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RADIOACTIVE DUST SAMPLING. PART 3: LONG-LIVED RADIOACTIVE DUST (LLRD) CHARACTERIZATION AND LLRD INSTRUMENT EVALUATION IN AN UNDERGROUND URANIUM MINE

J. BIGU, A. FRATTINI AND E. EDWARDSON

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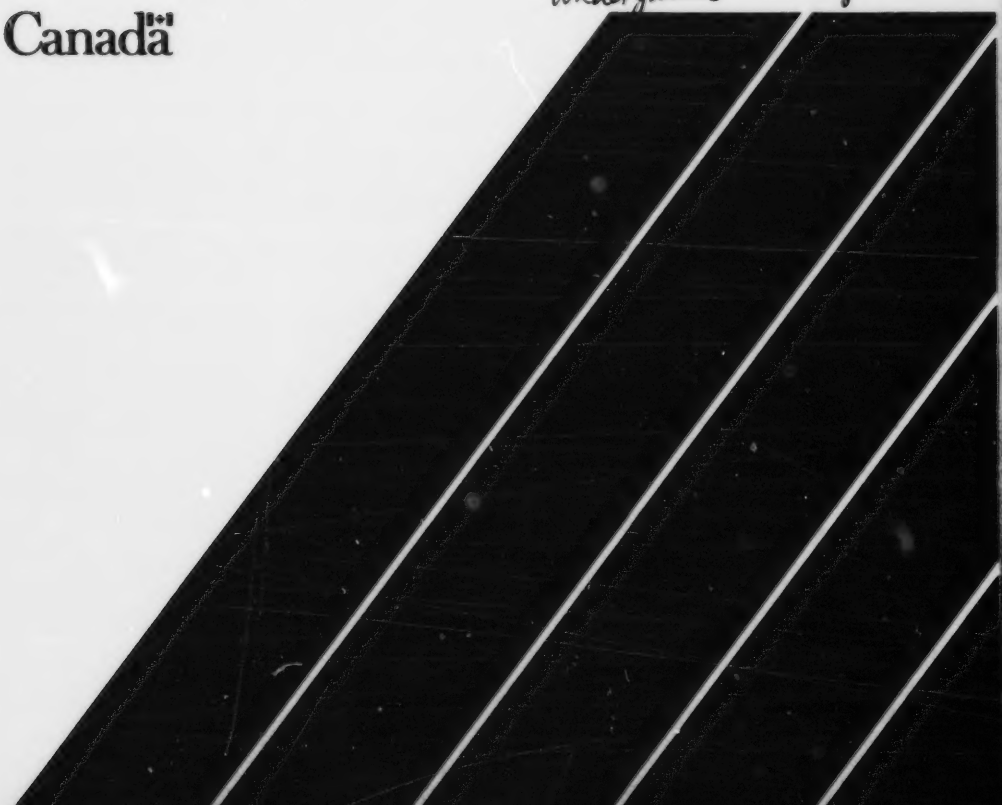

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J. Bigu*, A. Frattini** and E. Edwardson**

ABSTRACT

This technical report is part of a series of reports on the characterization of Long-Lived Radioactive Dust (LLRD) and the technical evaluation of several dust monitoring instruments in common use in specialized laboratory and field work, e.g., uranium mines and mills. The data reported here pertain to an experimental study conducted in an underground uranium mine (Stanleigh) in the Elliot Lake (Ontario) area. The study was carried out with a twofold purpose in mind, namely, for the characterization of dust and LLRD, and for the evaluation of a variety of monitoring instrumentation including cascade impactors, an optical particle counter, nylon cyclones, open-face filter samplers, and personal α-particle dosimeters (PADs), the latter normally used for α-particle radiation exposure purposes. Agreement between the data obtained using the above devices was from fair to good.

Key words: Radiation instrumentation; Radioactive dust; Dust.

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ÉCHANTILLONNAGE DE POUSSIÈRES RADIOACTIVES
3e PARTIE : CARACTÉRISATION DES POUSSIÈRES RADIOACTIVES À LONGUE PÉRIODE (PRLP) ET ÉVALUATION D'INSTRUMENTS DE MESURE DES PRLP DANS UNE MINE D'URANIUM SOUTERRAINE

J. Bigu*, A. Frattini** et E. Edwardson**

RÉSUMÉ

Le présent rapport technique fait partie d'une série de rapports concernant la caractérisation des poussières radioactives à longue période (PLRL) et l'évaluation technique de plusieurs instruments de surveillance des poussières utilisés couramment dans des travaux spécialisés effectués en laboratoire et sur le terrain, par exemple dans les mines et les usines d'uranium. Les données présentées ont trait à une étude expérimentale effectuée dans une mine d'uranium souterraine (Stanleigh) de la région d'Elliot Lake (Ontario). On a réalisé l'étude en visant un double objectif : la caractérisation des poussières et des PRLP et l'évaluation d'une variété d'instruments de surveillance, notamment des impacteurs en cascade, un compteur de particules optique, des cyclones en nylon, des dispositifs d'échantillonnage à filtres à face ouverte et des dosimètres alpha individuels, ces derniers étant normalement utilisés à des fins de mesure de la radioexposition alpha. La compatibilité entre les données obtenues au moyen des instruments susmentionnés était de passable à bonne.

Mots clés : instruments de mesure des rayonnements; poussières radioactives; poussières.

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INTRODUCTION

Mining operations generate dust emissions within a wide particle size range. Of particular interest from the occupational hygiene and health physics viewpoints are dusts generated in the respirable particle size range, namely, from less than 1 μm to about 10 μm. Dust in this particle size range, once inhaled, will be deposited in different parts of the respiratory system where they can pose a potential health hazard.

Dust generated in uranium mines contain the parents of the natural uranium and thorium radioactive decay chains as well as their long-lived and short-lived decay products. Because of the potential occupational health hazards associated with the inhalation of long-lived radionuclides contained in mine dust, hereafter referred to as Long-Lived Radioactive Dust (LLRD), its characterization is of great interest. However, precise characterization of LLRD requires reliable instrumentation.

The purpose of the present investigation was twofold:

1. To characterize LLRD in an underground (U/G) uranium (U) mine;
2. To evaluate (in the U/G U-mine above) the performance of a number of dust monitoring instruments commonly used in field and laboratory applications.

This work was requested by the Atomic Energy Control Board (AECB) as part of a contract awarded to CANMET (EMR), entitled "Comparison of Radioactive Aerosol Sampling Instruments", AECB Contract No. 4.108.1; Mining Research Laboratories (CANMET) Project No. 143902-14-4. The report presented here is part of phase 2 of the above contract which will be presented in five parts. The data in the report corresponds to part 3 of phase 2.

EXPERIMENTAL SITE

Work was carried out from November 27th to December 20th, 1990 in two working stopes in an underground uranium mine (Stanleigh) in the Elliot Lake area. A number of mining operations took place during LLRD characterization and instrument evaluation, including bolting, drilling, scaling, slushing, and mucking. Measurements were made downstream of the mining operations and at the exit, i.e., mouth, of the bulkheaded stopes which were provided with rectangular openings for air sampling and ventilation purposes. The stopes were exhausted into a main airway running at right angles to the stope. Figure 1A shows a layout of the experimental location where measurements were made, as well as some adjacent areas about the location of interest. The figure indicates the direction of airflow in the area. Figure 1B shows the stope openings and the location of the instrumentation used.

EXPERIMENTAL APPARATUS

Several dust monitoring instruments were evaluated and used for Long-Lived Radioactive Dust (LLRD) characterization, namely:

1. Cascade impactors (CI),
2. Nylon cyclones (NC),
3. Open-face filter samplers (OFFS),
4. Personal α-particle dosimeters (PADs), and
5. Optical particle counter (OPC).

Cascade impactors model Sierra 210 and Marple 290 (both distributed by Andersen, U.S.A.), PADs designed by the Commissariat a l'Energie Atomique (CEA, France) and an OPC model PDM-3 distributed by CGA (U.S.A.) were used. The open-face filter samplers used were of in-house design and were made up of commercially available open-face filter holders and sampling pumps. The nylon

cyclones were purchased from Levitt Safety Canada Ltd. (Toronto). The samplers and monitors indicated above have been described and discussed in detail in Part 1 of Phase 2 of this project (1), and will, therefore, not be discussed any further.

EXPERIMENTAL MEASUREMENTS AND PROCEDURES

A variety of measurements was made which include the following:

1. Dust characterization such as concentration and size distribution;
2. Radioactivity measurements such as ^{222}Rn and ^{220}Rn progeny concentration, e.g., Potential Alpha-particle Energy Concentration (PAEC), as well as $[^{218}Po]$, $[^{214}Bi]$, $[^{214}Pb]$ and $[^{214}Po]$, where the square brackets are used to denote activity concentration;
3. Long-Lived Radioactive Dust (LLRD) concentration and radioactivity (associated with the dust) size distribution;
4. Airflow measurements; and
5. Measurements of meteorological variables such as temperature (T), relative humidity (RH), and barometric pressure (P).

Measurements of the variables indicated in items 2, 4 and 5 were made on a daily basis. However, owing to the low dust concentration levels in this mine, daily dust characterization measurements (items 1 and 3) could not be performed with certain instruments, such as the Marple 290 (personal cascade impactor) because of the low operating airflow rate of this instrument (~2 L/min). For this reason, the cascade impactor substrates of the Marple 290 were not changed daily but were used for 2 or 3 days at a time depending on underground dust concentration conditions. (This sampling schedule was also related to the PAD sampling frequency as indicated below.) In order to be consistent as far as sampling procedures are concerned, the substrates of the other cascade impactor (Sierra 210), as well as the filters of the nylon

cyclones were also changed with the same frequency as that of the Marple 290 substrates. The OFFS were changed daily.

It has been indicated elsewhere (1) that the low sampling airflow rate of the PADs (~3.4 L/h) made it necessary for these devices to sample air for a minimum of 5 days (6 or 7 days in this U/G study) for a reliable reading to be attained. For this reason, and in order to be consistent with other dust sampling instrumentation and sampling schedules, the cascade impactors and nylon cyclones were operated for a period of either 2 days or 3 days. This sampling schedule greatly facilitated the comparison of data obtained by the PADs during sampling periods of either 6 days or 7 days with data obtained with the other instruments.

The OPC MiniRam PDM-3, being a dust monitor of the continuous type, provided dust concentration data on a 'real-time' basis, e.g., 6 independent readings per minute. Data with the open-face filter samplers were obtained daily.

Long-Lived Radioactive Dust concentration, [LLRD], versus particle size measurements were carried out using the cascade impactors Sierra 210 and Marple 290. On a few occasions, ^{220}Rn progeny α-particle activity measurements were conducted on the cascade impactor substrates of the Sierra 210 in order to estimate the AMAD corresponding to the ^{220}Rn progeny. Because of plate-out effects, and the limited capability of cascade impactors, such as those used here, to discriminate particles of size less than about 0.06 μm, the above instruments are not recommended for accurate measurements of the ^{220}Rn progeny's AMAD. The values obtained for this variable are, therefore, only approximate.

As previously indicated, ^{222}Rn progeny, airflow rate (Q), and T, RH, and P measurements were conducted concurrently with dust measurements. Furthermore, mining operations during the sampling periods were carefully recorded. There is little doubt that some of the above variables and

operations affect the [LLRD] and particle size distribution. However, no attempt has been made to investigate these relationships, which are beyond the scope of this report. Hence, meteorological data, airflow conditions, and ^{222}Rn progeny data are included in this report mostly for illustrative purposes and for the sake of completeness.

Characterization of dust and of the radioactivity associated with it are presented in this report in a number of different ways, namely:

1. Percentage (%) cumulative dust mass (or α-particle activity) less than the Equivalent Aerodynamic Diameter (EAD, $D_{p,50}$) versus particle size. This type of graph permits the Mass Median Aerodynamic Diameter (MMAD) or the Activity Median Aerodynamic Diameter (AMAD), as well as their respective geometric standard deviations (σ_g or GSD) to be obtained. This graph can be obtained from cascade impactor data;
2. Percentage (of the total) dust mass (or α-particle activity) versus cut-off particle size for the different stages of the cascade impactors. This type of data are presented here as line graphs and as histograms (bar graphs);
3. Dust mass concentration (mg/m^3) versus time. This kind of graph is obtained from OPC's data (i.e., MiniRam PDM-3). As previously indicated, this device is of the continuous type and therefore provides data every minute. The MiniRam was operated in the passive mode in these series of measurements, i.e., without a sampling pump (1); and
4. Dust mass concentration (mg/m^3) and LLRD concentration, [LLRD], mBq/m^3, from grab-sampling data obtained with the nylon cyclones, PADs, open-face filter samplers, as well as the cascade impactors. These data appear mostly in tabular form.

It should be noted that the graphs corresponding to item 1, namely, MMAD and AMAD graphs, are labelled, Dust: Nat. LLRD where Nat. stands for natural and LLRD stands, as usual, for Long-Lived Radioactive Dust. The

'label' Nat. LLRD simply indicates that the sampling is done in a natural atmosphere containing LLRD as opposed to 'man-made' dusts injected into the Long-Lived Radioactive Dust Test Facility (LLRDTF) for laboratory work, e.g., Al_2O_3, SiC, flour, talcum and starch. These dusts, in conjunction with the LLRDTF, were used, under laboratory controlled conditions, to evaluate the dust monitoring instruments used in this study. The same labelling as before, namely, Nat. LLRD, was used in the uranium mill studies which are the subject of a separate report.

The techniques, methodology, and protocol used here for gathering and analyzing data are the same as those amply documented elsewhere (2). The instruments evaluated, also used in the characterization of dust, were confined to a relatively small volume of the working stope to ensure sampling under identical airflow and dust concentration conditions.

The following section presents and discusses the experimental data obtained during the instrument evaluation and LLRD characterization studies.

EXPERIMENTAL RESULTS AND DISCUSSION

The experimental results obtained in these studies have been summarized in Tables 1 to 6, Figures 2 to 65, and Figures A1 to A20 of Appendix A. Because of the bulk of the data, and for the sake of simplicity, the data will be presented and discussed in several sub-sections.

Of general interest in the context of this report are Tables 1 to 3 which show, respectively, the daily mining operations performed, meteorological conditions underground, such as T, R, RH, and airflow rate (Q), and ^{222}Rn progeny and ^{220}Rn progeny data.

1. MASS MEDIAN AERODYNAMIC DIAMETER (MMAD) AND ACTIVITY MEDIAN AERODYNAMIC DIAMETER (AMAD) DATA

MMAD and AMAD data are shown in Figures 2 to 29. The graphs have been grouped chronologically and all correspond to studies conducted during 1990. The different graphs correspond to the following dates:

Figures 2 to 7 : November 29th to 30th;

Figures 8 to 13 : December 4th, 5th and 6th;

Figures 14 to 18 : December 7th and 10th;

Figures 19 to 24 : December 13th, 14th and 17th;

Figures 25 to 29 : December 18th, 19th and 20th.

The first and second illustration of each group correspond to the MMAD obtained from data gathered with the Sierra 210 and Marple 290, respectively. The other illustrations in the group correspond to the AMAD obtained by the same instruments in the same order. If ^{220}Rn progeny AMAD data are available, the corresponding illustration appears as the last of the group. The reader may ask the reason for measuring ^{220}Rn progeny size distribution rather than ^{222}Rn progeny size distribution. The reason is simple: the short half-life of the ^{222}Rn progeny presented certain measurement difficulties difficult to accommodate within the underground mine measurement protocols. However, ^{220}Rn progeny measurements could be carried out easily in the laboratory after the daily mine-working shift. Because of the similarity between ^{222}Rn progeny and ^{220}Rn progeny, the radioactivity size distribution for the former is not expected to differ significantly from the radioactivity size distribution corresponding to the ^{220}Rn progeny.

Table 4 shows a summary of MMAD and AMAD data presented in Figures 2 to 29. These data show the following:

1. The MMAD and AMAD data obtained with the Sierra 210 were significantly lower than the data obtained with the Marple 290, i.e., 39% for the MMAD

and 49% for the AMAD. These figures represent average values taking all the data into consideration;

2. The values for the AMADs obtained with both the Sierra 210 and the Marple 290 were markedly higher than the values obtained for the MMAD corresponding to the carrier dust. The relationship of the values for the above variables, represented by the ratio AMAD/MMAD, was 1.35 for the Sierra 210 and ~1.50 for the Marple 290. These values are significantly higher than the values obtained in the past in other experimental work. The reasons for the AMAD being substantially larger than the MMAD of the carrier dust are not altogether clear. Uncertainties in dust mass determination, as well as α-particle self-absorption effects, and other phenomena are, of course, factors that could play an important role in explaining the discrepancies observed; and
3. The ranges of values for the MMAD and AMAD measured for the two instruments were as follows:

Sierra 210	MMAD	: 2.2 μm to 3.7 μm
	AMAD	: 1.8 μm to 5.2 μm
Marple 290	MMAD	: 1.8 μm to 5.4 μm
	AMAD	: 2.5 μm to 8.1 μm

Although the relatively wide ranges of values observed for the MMADs and the AMADs (i.e., ratio of ~3 from maximum to minimum values) are reasonable and consistent with different mining operations and other considerations, such as wetting practices, distance from dust source(s), and airflow conditions, the reasons for the lack of better agreement between the Sierra 210 and the Marple 290 are somewhat worrying. The results obtained in this underground mine study suggest that the agreement between the Sierra 210 and the Marple 290 is at best fair and at worst, poor.

It cannot be stressed sufficiently that it is virtually impossible to characterize dust generated in conventional mining operations using grab-

sampling 'time-integrating' devices (in this case cascade impactors) under normal field conditions. One of the reasons is the duration of a particular mining operation, e.g., drilling and mucking, which is on the average substantially shorter than the time necessary for the instrument to collect enough sample (e.g., dust mass or number of dust particles) for accurate analysis. (This can be demonstrated by inspecting Table 1 and noting that an 8 h sampling period is normally necessary to obtain good results, statistically, for the cascade impactors used here.)

From the above, it may be surmised that the cascade impactors used here 'see' a variety of mining operations during their sampling periods. Furthermore, the situation depicted above is aggravated by the sometimes occasional, but mostly frequent changes in airflow conditions, as well as the passing of heavy vehicles that 'push' the dust clouds, and the frequent change of the distance between the dust source(s) and the location of the sampling instrumentation. It should be noted, however, that other kinds of instrumentation that respond instantaneously, or at least very quickly, to airborne dust changes are capable of certain types of dust characterization under varying mine operation conditions. Instruments of this kind include the MiniRam PDM-3, the Climet CI-7000, and the cascade impactor QCM (3).

Because of what has been adduced above, the difficulties in finding a clear relationship between the MMADs, AMADs, mining operations and activities, and airflow conditions should come as no surprise.

It should be noted that depending on the type of mining activity (i.e., mining operation in conjunction with the operation of mining tools and vehicles, etc.) the particle size distributions of the dust clouds measured are bimodal, i.e., made up of a coarse particle size contribution and a fine size fraction, the latter arising from diesel particulates and mists generated by the operation of mining equipment, tools and vehicles. As expected, and owing to the reason given above, while some of the measurements show this

bimodal distribution, some others do not. The reader will note that in the majority of cases a straight line has been drawn through the data points. This line corresponds to the best-fitted line by linear regression analysis drawn through the coarse dust fraction, which for all cases measured here is the fraction of interest for the calculation of the MMAD and AMAD.

Finally, the values obtained for the AMADs corresponding to the ^{220}Rn progeny were in the range 0.20 μm to -0.26 μm, values which, although only approximate, are consistent with the values expected for the ^{220}Rn progeny in a mine environment.

2. DUST MASS AND α-PARTICLE ACTIVITY VERSUS PARTICLE SIZE DISTRIBUTION

The data shown in Figures 2 to 29 do not render themselves to easy intuitive interpretation. A more readily understandable kind of data are those shown in Figures 30 to 49 which show the percentage of dust mass (of the total mass) versus particle cut-off diameter (Figures 30 to 39), or the percentage of α-particle activity (of the total activity) versus particle cut-off diameter (Figures 40 to 49). These data were obtained, as before, with the cascade impactors Sierra 210 and Marple 290, and they show similar data as before but presented in a different way. A close inspection of Figures 30 to 49 show maxima which are, as expected, close to the values calculated for the MMADs and AMADs shown in Figures 2 to 29 and Table 4, where the percentage cumulative dust mass or α-particle activity has been plotted against the particle cut-off size of the cascade impactor stages.

It goes without saying that a close inspection of the data in Figures 30 to 49 indicates clearly that the Sierra 210 'behaves' significantly better than its counterpart, the Marple 290. There is little doubt also that Figures 30 to 49 provide a better indication of dust characterization, such as particle size and α-particle distributions than Figures 2 to 29.

Slightly different versions for Figures 30 to 49 are shown in Figures A1 to A20 in Appendix A. These figures show histograms representing the percentage of dust mass, or α-particle activity, versus particle cut-off diameter as measured from data collected with the Sierra 210 and the Marple 290. The figures have been arranged in a different way to Figures 30 to 49 for more direct comparison purposes of dust mass or α-particle activity obtained by the two cascade impactors under consideration. Thus, the histograms have been grouped following a specific order for ease of analysis, namely:

a) Percentage dust mass versus cut-off diameter followed by the percentage α-particle activity versus cut-off diameter, both graphs for the Sierra 210, followed by:

b) The same as item a) but for the Marple 290.

The above graph sequence permits easy comparison of dust mass size distribution and α-particle activity distribution for each cascade impactor. With regards to the above, the following items are worth mentioning:

a) Except for some cases, a direct comparison of the dust mass and α-particle activity distributions obtained with either instrument does not suggest close similarity and correspondence between these two distributions;

b) In spite of item a), the correspondence between dust mass distribution and α-particle activity distribution is substantially better for the Sierra 210 than for the Marple 290.

Again, the reasons for the discrepancies observed are not clear, but weighing errors and α-particle self-absorption effects are suspected to play some role. This topic will be dealt with in more detail in another report.

In spite of the differences indicated in items 1) and 2), a clear relationship is observed between the total dust mass and the total α-particle activity measured with the Sierra 210 and the Marple 290 for two distinct sampling periods, namely, from November 29th to December 10th, and from

December 13th to December 20th (see Table 4).

Calling [S210] and [M290], respectively, the total dust mass collected by the Sierra 210 and Marple 290 and [LLRD(S210)] and [LLRD(M290)] the long-lived α-particle activity measured with the Sierra 210 and Marple 290, respectively, Table 4 shows the following:

a) The average [S210] for the first sampling period (November 29th to December 10th) was 0.97 mg/m^3, whereas it was 2.01 mg/m^3 for the second sampling period (December 13th to 20th). The ratio of these two values (2nd sampling period to 1st sampling period) was 2.01/0.97 = 2.07. For the Marple 290, the values obtained were 0.91 mg/m^3 and 1.52 mg/m^3 for the 1st and 2nd sampling periods, respectively. The ratio of these values is 1.67. It is clear from these figures that a substantial increase in airborne dust mass concentration took place during the second sampling period when compared with the first sampling period, as evidenced from experimental data obtained independently with these two cascade impactors. (It should be noted that the dust mass concentrations obtained with the Sierra 210 and Marple 290 were quite close for the first sampling period and relatively close for the second sampling period, particularly taking into account the experimental difficulties of the study.); and

b) Similar calculations to those conducted in item a), but for airborne [LLRD] obtained with the two cascade impactors gave the following results: [LLRD(S210)] = 59.7 mBq/m^3 for the first sampling period, and 156.5 mBq/m^3 for the second sampling period. Similarly, the following values were obtained for the Marple 290: 51.67 mBq/m^3 and 146.5 mBq/m^3 for the first and second sampling periods, respectively. The agreement obtained with these two instruments was quite good, and the ratio of [LLRD] for the two sampling periods was very similar, namely, 2.62 for the Sierra 210 and 2.83 for the Marple 290.

The data of items a) and b) have been summarized below for the benefit

of the reader. Information on the specific radioactivity, e.g., [LLRD(S210)]/[S210], is also included below:

Sampling Period (1990)	[S210] (mg/m^3)	[M290] (mg/m^3)	[LLRD(S210)] (mBq/m^3)	[LLRD(M290)] (mBq/m^3)
Nov. 29th to Dec. 10th	0.97	0.91	59.7	51.7
Dec. 13th to Dec. 20th	2.01	1.52	156.5	146.5

The ratios of dust mass concentration corresponding to the second sampling period (indicated by the subindex 2) relative to the first sampling period (indicated by the subindex 1) were:

$$[S210]_2/[S210]_1 = 2.07;$$

$$[M290]_2/[M290]_1 = 1.67;$$

$$[LLRD(S210)]_2/[LLRD(S210)]_1 = 2.62; \text{ and}$$

$$[LLRD(M290)]_2/[LLRD(M290)]_1 = 2.83.$$

(It should be noted that the LLRD activity ratios are larger than those corresponding to the dust mass ratios.)

For the specific activity, the following values were obtained:

Sampling Period (1990)	$\frac{[LLRD(S210)]}{[S210]}$ (mBq/mg)	$\frac{[LLRD(M290)]}{[M290]}$ (mBq/mg)
Nov. 29th to Dec. 10th	61.5	56.8
Dec. 13th to Dec. 20th	77.9	96.4

with average values of 69.7 mBq/mg and 76.6 mBq/mg, for the two sampling periods combined, which is fairly good.

We will show that similar data trends to those discussed above were also observed for other instrumentation.

3. DUST MASS CONCENTRATION MEASURED USING THE MINIRAM MODEL PDM-3

From all the instruments used for dust characterization in this underground uranium mine study, the MiniRam Model PDM-3 was the only one of a continuous type, i.e., provides dust concentration data continuously at 1 min intervals. This instrument, therefore, permits the study of the presence of airborne dust in mine air as a function of time. Hence, dust quantification of different mining operations and mining activities that either generate or remove dust from mine air is possible.

The MiniRam did not operate satisfactorily all the time. It proved to be sensitive to high relative humidity levels, and under harsh conditions it malfunctioned repeatedly. This problem was eventually solved by carefully sealing the instrument case with silicone sealant. The instrument also exhibited dust contamination of the optical system, and hence, a steady increase in the background concentration which translated into a zero drift.

Figures 50 to 60 show daily dust concentration data obtained with the MiniRam. It is interesting to compare the above figures with the data shown in Table 1, where the different mining operations, activities and times at which they occurred, and periods they lasted, are tabulated.

Again, it is not easy to correlate the information shown in Table 1 and the data of Figures 50 to 60 because mining staff and vehicles moved around, airflow conditions changed, and a multitude of other activities took place concurrently. The extreme variability in airborne dust concentration measured by the instrument is worth mentioning. It should be noted that the presence and motion (about the instrument) by the researchers also has a significant effect on the performance of the instrument. Unfortunately, this type of interference is unavoidable.

The short bursts, or dust concentration spikes shown in some of the graphs are caused by the sudden start of some activity, including walking of

personnel, and particularly, passing vehicles. There is little doubt that despite the documentation provided in Table 1, the information is insufficient to correlate it with Figures 50 to 60. The reasons for this are simple, namely:

a) No single mining operation or activity was sustained, without interruption, for extended periods. Frequent interruptions ranging from about 1 min to more than 5 min occurred. Hence, the intervals in Table 1 cannot be taken literally. They are mainly meant to give an indication of the period during which a given job, operation, activity, and the like took place;

b) Changes in airflow conditions were not unusual, as Table 2 shows. It should be noted that the mine airflow rate was measured every hour. Hence, airflow changes between measurements are not only likely, but most certain, without the knowledge of the operator(s). Airflow conditions affect the deposition pattern of dust clouds and hence their concentration and size distribution;

c) The distance between the dust source(s) and the monitoring instrumentation varied frequently as a variety of mining operations such as drilling, bolting, scaling, slushing, and mucking, as well as other activities including wetting, took place at different locations of the working sites;

d) Measurements were carried out in two stopes adjacent to each other (see Figure 1). The stopes had the same approximate length, but different cross-sectional area. Furthermore, the airflow rates for the two stopes were different.

The combination of items a) to d), and other considerations, give an idea of the difficulties arising when trying to correlate the above with Figures 50 to 60. Something that can be said with certainty is that periods of no mine 'activity' are characterized by low dust concentrations. The converse is equally true. It should be noted that for reasons given

previously no attempt has been made to single out any particular mining operation and relate it to the response of the MiniRam. What has been done, however, is to average the dust mass concentration measured by the instrument for each work-day-shift and to compare these data with data obtained from other instruments. The range of dust mass concentration values read by the monitor was from less than 0.02 mg/m^3 to >6 mg/m^3. The latter values were only attained occasionally and for short periods. The average daily values for the dust concentration obtained with the MiniRam model PDM-3 are shown in Figure 61. These average values ranged from ~0.1 mg/m^3 to ~0.7 mg/m^3.

4. DUST CONCENTRATION CALCULATED FROM PAD'S DATA

In this underground study, the PADs were used twice. Two units (PADs) were used each time. The two sampling periods lasted for 7 days (first run) and 6 days (second run). The dates the devices were used, the sampling times for each work shift, the airflow rate at which the PADs were operated, and the air volume sampled by the devices are shown in Table 5. Also shown in this table are the total dust mass collected on the filters as well as the (calculated) airborne dust concentration and Long-Lived Radioactive Dust (LLRD) concentration, i.e., [LLRD], where the square brackets are used in this report to indicate activity concentration. (Note: in the Table, [LLRD] is referred to as 'Activity'.)

Table 5 shows that the airborne dust mass concentration measured by the PADs was 2.98 mg/m^3 for the first run of 7 days, and 5.30 mg/m^3 for the second run of 6 days. The values given above represent the averages of the two PADs. These values are substantially higher than the values obtained using the open-face filter sampler (see Table 6). There is no clear reason for the discrepancy between these two devices. If anything, one would expect the PADs to 'read' lower than the open-face filter sampler simply because in the first

case air is sampled through 3 small orifices where the potential for coarse particle removal is not negligible. In essence, the PADs are 'equipped' with some particle size selection characteristics. Because of the size cut-off characteristics and limitations of cascade impactors and nylon cyclones, and the limited particle size range of the MiniRam (~1 μm to 10 μm), it is clear that both the PADs and the open face filter sampler should collect more dust than the other instruments, as is the case (see Table 6).

The α-particle activity corresponding to the Long-Lived Radioactive Dust (LLRD) collected on the filters of the PADs were also measured and the airborne [LLRD] was calculated. The average values obtained for the [LLRD] were as follows:

Sampling from November 29th to December 10th : 78 mBq/m^3, and

Sampling from December 13th to December 20th : 418 mBq/m^3.

The above values represent, in each case, the average value of the two PADs used in the evaluation. The ratio of the LLRD concentration, [LLRD], for these two periods, namely: 418/78 = 5.36 contrasts markedly with the ratio of the dust mass for the same periods, i.e., 5.30/2.98 ~1.8 (see Table 5 for these data). One would suspect these data were it not that other independent measurements with other instrumentation show similar results (see Table 6).

The substantial difference observed between the radioactive dust concentrations, [LLRD], for the two sampling periods could be attributed to one or more of the following reasons:

1. The grade of the ore mined was higher for the second sampling period than for the first period;
2. The long-lived radionuclides are selectively associated with dust particles of a specific size range or size ranges;
3. The dust particle size distributions for the two sampling periods were different. It should be noted that items 2 and 3 could be viewed as complementary or interrelated.

Indeed, differences in size distributions have been observed (item 3) as the data shown below (summarized from the data of Table 4) shows:

Sampling Period 1990	MMAD(S210) (μm)	MMAD(M290) (μm)	AMAD(S210) (μm)	AMAD(M290) (μm)
Nov. 29th to Dec. 10th	2.32	3.25	3.04	4.48
Dec. 13th to Dec. 20th	3.60	4.93	5.08	7.62

Sampling Period (1990)	MMAD(S210 + M290) (μm)	AMAD(S210 + M290) (μm)
Nov. 29th to Dec. 10th	2.79	3.76
Dec. 13th to Dec. 20th	4.26	6.35

where, in the above tabulated data, S210 and M290 are used to indicate, respectively, Sierra 210 and Marple 290. Furthermore, the notation (S210 + M290) is used to indicate the average value for data obtained for the Sierra 210 and Marple 290. It is a simple matter to show that the ratios of MMADs or AMADs (values corresponding to the second sampling period divided by the values corresponding to the first period) are in the range 1.52 to 1.70. It may be concluded that the MMADs and AMADs corresponding to the second sampling period were larger than those corresponding to the first sampling period, giving credence to item 3, and hence hinting at the possibility of item 2, both in the preceding list.

5. OPEN-FACE FILTER SAMPLER AND NYLON CYCLONES DATA

The data obtained with the open-face filter sampler (OFFS) and the nylon cyclones (NC) are shown in Table 6. Because the OFFS and NCs collect

dust on a filter, unlike the MiniRam, the filter can be used to determine both airborne dust mass concentration and α-particle activity concentration by measuring, as with other instruments such as the cascade impactors, the weight of the dust deposited on the filter and the α-particle activity associated with the dust.

Because the size cut-off of the NCs, devices designed for estimating respirable dust concentration for occupational hygiene and regulatory purposes, the dust concentration measured by these devices is substantially lower, on the average, than the concentration measured by the OFFs. The same applies when comparing the NCs with the cascade impactors, devices that have a much higher size cut-off, i.e., >20μm, depending on operating airflow conditions. Values for the dust concentrations for these devices are shown in Table 6. It should be noted that the data obtained with the OFFs are shown in the above table under the heading 'Total Dust'.

As previously indicated, the open-face filter sampler (OFFS) should collect the highest dust mass, higher than the nylon cyclones (NC) and other instrumentation evaluated. This is the case when the responses to airborne dust for the OFFS and the NCs are compared. The ratio between the airborne dust mass concentration measured by the OFFS, [OFFS], and that corresponding to the NCs, [NC], namely [OFFS]/[NC], as well as the ratio corresponding to their respective α-particle activities, namely [LLRD(OFFS)]/[LLRD(NC)], are given below:

Sampling Period	[OFFS]/[NC]	[LLRD(OFFS)]/[LLRD(NC)]
November 29th, 30th	2.77	2.6
December 4th, 5th, 6th	2.49	3.7
December 7th, 10th	4.45	11.2
December 13th, 14th, 17th	4.70	8.1
December 18th, 19th, 20th	3.52	7.4

The above data show that:

1. The mass ratio [OFFS]/[NC] ranges from about 2.5 to 4.7, and the α-particle activity ratio [LLRD(OFFS)]/[LLRD(NC)] ranges from 2.6 to about 11;
2. The above ratios are grouped into two clearly distinguishable ranges of values corresponding to the sampling periods November 29th to December 4th, and December 7th to December 20th;
3. The activity ratios are higher than the mass ratios.

These results partially support the conclusions reached in the previous sub-section (discussion of the PADs performance), namely, that there was a change in the dust particle distribution which, for the devices under discussion, is evidenced by the differences in the above ratios. A simple argument will clarify this. Because of the 'fixed' relatively low particle cut-off size for the nylon cyclones, NC, an increase in the size of the dust particles (i.e., increase in the MMAD of the distribution, etc.) will show as an increase in the ratio [OFFS]/[NC]. A similar argument along the lines discussed in the previous sub-section (PADs) can be used for the case of the LLRD radioactivity associated with the dust.

The data shown above also reveal new insights into this matter. Because the sampling schedule for the OFFS and NCs, as well as for the rest of the instrumentation tested (except for the MiniRam), was slightly different to that for the PADs, the data show that the 'transition' to larger particle size distribution must have occurred between the periods of November 29th to December 6th, and December 13th to December 20th, namely, somewhere on December 7th or December 10th.

Again we are able to verify the veracity of the radioactivity data obtained for the PADs, namely, the airborne [LLRD] for the second sampling period was significantly higher than that for the first sampling period.

Figures 62 and 63 show histograms of the airborne dust mass

concentration and the Long-Lived Radioactive Dust concentration, [LLRD], respectively, obtained for different dates using the open-face filter sampler (OFFS). These histograms confirm once more, and in a more graphical form than the tabulated data, the different underground mine conditions that prevailed for the various sampling days of the underground tests. In particular, the histograms show that the value of the above variables were significantly higher during the period December 10th to December 20th, than during the period November 29th to December 7th, as determined by the OFFS.

COMPARISON OF DATA OBTAINED WITH THE DIFFERENT INSTRUMENTATION USED

A partial summary of the data obtained with the different sampling devices evaluated is given in Figures 64 and 65. Figure 64 shows dust mass concentration data whereas Figure 65 shows Long-Lived Radioactive Dust concentration, [LLRD], data.

Figures 64 and 65 show that except for one case (sampling period: November 29th and 30th), the open-face filter sampler (OFFS) gave, as expected, the highest values for dust mass concentration and [LLRD]. Furthermore, the values for both variables obtained with the Sierra 210 and Marple 290 were very similar. In all cases, dust mass concentration obtained with the MiniRam Model PDM-3 was significantly lower than the values obtained with the other instrumentation. The nylon cyclones (NC) gave values for [LLRD] and dust mass concentration somewhere between the values obtained for the OFFS and the cascade impactors Sierra 210 and Marple 290.

In general, and except for some discrepancies in some of the data obtained with the PADs and the MiniRam, the instrumentation evaluated in the underground uranium mine behaved as expected, and fair to good agreement was found between the different devices used if allowance is made for the different characteristics of each instrument such as particle size range

(e.g., Sierra 210 and Marple 290) and size cut-off (e.g., nylon cyclones and open-face filter sampler).

The data presented in this report are only a fraction of all the data obtained in the course of several related studies. In subsequent reports, data obtained under 'laboratory-controlled' conditions and in two uranium mills will be presented and discussed. General conclusions on dust characterization and instrument evaluation will be deferred to a special .LH12 summing-up report.

REFERENCES

1. Bigu, J., "Radioactive dust sampling. Part 1 - Laboratory test facilities and sampling instrumentation used"; Report in compliance with AECB Contract No. 4.108.1, entitled "Comparison of Radioactive Aerosol Sampling Instruments", Phase 2, Part 1, 1991.

2. Bigu, J. and Grenier, M., "Characterization of radioactive dust in Canadian underground uranium mines"; Proc 2nd U.S. Mine Ventilation Congress, P. Mousset-Jones (Ed.), Reno, Nevada, A.A. Balkema, Rotterdam, pp. 269-277, 1985.

3. Bigu, J., "A review of airborne particle sampling with special reference to Long-Lived Radioactive Dust"; Report in compliance with AECB Contract No. 4.108.1, entitled "Comparison of Radioactive Aerosol Sampling Instruments", Phase 1, 1990.

Table 1 - Mining activities at two working stopes (32265E and 32265W) at Stanleigh Mine.

Date 1990	Location	Duration	Activity
Nov. 29th	32265E	08:30-13:00	Drilling
		13:25-13:39	Lost 110 V power
		13:30-end of shift	Loading
Nov. 30th	"	08:15-08:30	Wetting muck
		08:30-10:30	Bolting
		10:30-12:30	Drilling
		13:10-14:15	Loading
Dec. 4th	"	08:20-09:00	Setting up slusher
		09:00-12:00	Slushing
		12:20-14:15	Bolting
Dec. 5th	"	09:30-10:00	Wetting muck
		10:00-12:30	Slushing
		12:30-12:50	Installing slusher blocks ~2 m from samplers
		13:00-14:18	Slushing
		14:18-end of shift	Washing down face
Dec. 6th	"	08:20-08:45	Wetting muck
		08:45-09:30	Slushing
		09:30-12:00	Slushing
		12:20-end of shift	Bolting
Dec. 7th	"	08:20-09.20	Wetting muck
		09:30-13:50	Slushing
Dec. 10th	"	08:50-10:35	Bolting
		11:05-13:45	Drilling
		13:45-end of shift	Loading

Cont.

Table 1 - cont.

Date 1990	Location	Duration	Activity
Dec. 13th	32265W	08:45-09:50	Scaling
		09:50-12:00	None
		12:00-13:05	Drilling
		13:05-14:00	Loading
Dec. 14th	"	08:40-09:00	Wetting muck
		09:30-10:45	Slushing
		10:45-13:30	Drilling
		13:30-end of shift	None
Dec. 17th	32265E	08:30-09:09	Slushing
		09:09-10:07	Stench gas (fire drill) pumps left running
		10:22-13:30	Slushing
		13:30-end of shift	None
Dec. 18th	32265W	08:30-09:40	Wetting muck
		10:10-end of shift	Bolting & scoop mucking (infrequent)
Dec. 19th	"	09:30-10:00	Wetting muck
		10:00-14:00	Slushing & scoop mucking
Dec. 20th	"	08:15-09:00	Wetting muck
		09:00-14:10	Scoop mucking (infrequent)

Table 2 - Meteorological data at the underground location where measurements were conducted.

Date	Time	D.B. Deg.C	W.B. Deg.C	Air Volume (m^3/min)	Bar. Pres. (mb)	Relative Humidity %
NOV 28 90	850	16.40	15.2	143.6	1058.0	92
	945	16.50	15	135.6		85.50
	1045	16.50	15.2	178.4	1059.0	87.50
	1215	16.50	15.5	210.1	1062.0	90.00
	1320	16.40	15.5	210.1		92.50
	1415	16.50	15.7	248.9		92.00
	AVERAGE:	16.47		187.79	1059.7	89.92
	STD:	0.05		39.77	1.7	2.60
NOV 29 90	800	16.60	16.1	208.3	1085.0	95.00
	900	16.40	15.5	209.2	1084.0	91.00
	1000	15.70	15.1	228.4	1086.0	94.00
	1100	15.90	15.2	210.5	1086.0	93.00
	1200	15.80	15.1	201.2	1086.0	93.00
	1300	15.90	15.1	225.7	1086.0	92.00
	1400	15.70	15.1	212.8	1086.0	92.00
	AVERAGE:	16.00		213.72	1085.6	92.86
	STD:	0.33		9.08	0.7	1.25
NOV 30 90	815	16.40	15.9	254.2	1083.0	95.00
	915	15.80	15.2	261.8	1082.0	94.00
	1005	15.50	15	247.6	1082.0	95.00
	1110	15.40	14.9	232.4		95.00
	1215	15.40	15.1	251.1	1079.0	97.00
	1310	15.80	15	240.4	1079.0	92.00
	1415	15.80	15.1	260.5	1079.0	93.00
	AVERAGE:	15.73		249.72	1080.3	94.43
	STD:	0.32		9.83	1.7	1.50
DEC 4 90	820	16.50	15.2	262.3	1074.0	87.50
	901	15.50	14.7	248.0	1073.0	92.00
	1030	15.40	14.5	273.0	1073.0	91.00
	1200	15.10	14.4	252.0	1073.0	93.00
	1325	15.00	14.3	271.6	1073.0	93.00
	1415	15.00	14.3	266.7	1073.0	93.00
	AVERAGE:	15.42		262.28	1073.2	91.58
	STD:	0.32		9.41	0.4	1.97
DEC 5 90	900	15.00	14	220.8	1082.0	90.00
	1015	15.00	14.4	248.0	1082.0	94.00
	1230	15.10	14.4	222.6	1082.0	93.00
	1315			269.0		
	1400	16.00	15	271.6	1080.0	90.00
	AVERAGE:	15.28		246.40	1081.5	91.75
	STD:	0.42		21.78	0.9	1.79
DEC 6 90	820	16.30	15.4	235.1	1072.0	91.00
	930	15.40	14.5	280.6	1072.0	91.00
	1015	15.10	14.3	269.4	1072.0	92.00
	1115	15.40	14.6	268.5	1072.0	92.00
	1220	15.30	14.5	277.4	1076.0	92.00
	1315	15.20	14.4	281.0	1076.0	92.00

cont.

Table 2 cont.

	1410	15.30	14.5	268.5	1076.0	92.00
	AVERAGE:	15.43		268.65	1073.7	91.71
	STD:	0.37		14.64	2.0	0.45
DEC 7 90	820	15.90	15.2	230.2	1077.0	93.00
	920	15.60	14.9	220.3	1077.0	93.00
	1025	15.50	14.5	196.3	1077.0	90.00
	1100			54.4		
	1115	15.50	14.8	71.4	1077.0	93.00
	1225	15.00	14.5	170.8	1076.0	95.00
	1350	15.40	14.9	177.5	1076.0	95.00
	AVERAGE:	15.48		160.13	1076.7	93.17
	STD:	0.27		64.71	376.8	1.67
DEC 10 90	850	15.90	14.8	194.5	1084.0	89.00
	1000	15.30	14.5	243.1	1084.0	92.00
	1105	14.80	14.2	140.1	1084.0	94.00
	1240	14.70	14.1	178.4	1084.0	94.00
	1400	15.20	14.5	168.6	1084.0	93.00
	AVERAGE:	15.18		184.93	1084.0	92.40
	STD:	0.43		34.05	0.0	1.85
DEC 13 90	840	16.50	15	66.0	1071.0	85.50
	650	15.30	14.8	69.0	1074.0	95.00
	1055	15.80	14.8	76.9	1075.0	90.00
	1215	15.50	14.8	56.4	1078.0	93.00
	1305	16.80	15.3	103.9	1078.0	86.00
	1400	15.70	15	85.1	1080.0	93.00
	AVERAGE:	15.93		76.21	1076.0	90.42
	STD:	0.54		15.26	3.0	3.61
DEC 14 90	840	16.40	15	67.6	1091.0	86.00
	940	15.80	15	77.2	1091.0	92.00
	1040	15.90	15	118.8	1091.0	91.00
	1220	16.20	15.1	88.8		89.00
	1330			0.0	1090.0	
	1400	15.90	15.1	95.7		92.00
	AVERAGE:	16.04		74.68	1090.8	90.00
	STD:	0.22		37.01	0.4	2.28
DEC 17 90	830	15.50	15	165.9	1082.0	95.00
	1022	15.00	14.5	134.7	1081.0	95.00
	1115	15.00	14.5	110.6	1080.0	95.00
	1235	15.00	14.5	151.2	1079.0	95.00
	1330	15.00	14.5	133.4	1078.0	95.00
	1410	15.10	14.5	134.7	1077.0	94.00
	AVERAGE:	15.10		138.42	1079.5	94.83
	STD:	0.17		17.06	1.7	0.37
DEC 18 90	830	15.50	14.8	96.3	1060.0	93.00
	940	15.10	14.6	101.0	1060.0	95.00
	1055	15.60	14.7	100.0	1060.0	91.00
	1230	15.60	14.7	73.9	1060.0	91.00
	1405	16.00	15	98.7	1061.0	90.00
	AVERAGE:	15.56		93.97	1060.2	92.00
	STD:	0.26		10.15	0.4	1.79

cont.

Table 2 - cont.

DEC 19 90	830	15.80	14.8	98.7	1083.0	90.00
	930	15.00	14.5	71.3	1084.0	95.00
	1038	15.40	14.9	104.6	1085.0	95.00
	1120	15.40	14.8	85.1	1086.0	94.00
	1250	15.50	14.8	92.1	1087.0	93.00
	1355	15.40	14.8	87.8	1087.0	94.00
	AVERAGE:	15.42		89.91	1085.3	93.50
	STD:	0.23		10.58	1.5	1.71
DEC 20 90	815	15.20	14.7	73.2	1093.0	95.00
	906	15.10	14.6	69.3	1093.0	95.00
	1000	15.40	14.8	97.0	1092.0	94.00
	1105	15.50	15	113.5	1092.0	95.00
	1200	15.50	14.9	153.1	1092.0	94.00
	1330	16.00	15.1	164.0	1089.0	91.00
	1410	15.90	15	157.4	1087.0	91.00
	AVERAGE:	15.51		118.21	1091.1	93.57
	STD:	0.31		37.29	2.1	1.68

Table 3 - ^{222}Rn and ^{220}Rn progeny data at the location where dust sampling was conducted.

Grab samples (Thomas) Stanleigh u/g Nov/Dec 90

Date	Time	Wl(Rn)	PAEC(Rn) (uJ/m3)	Wl(Tn)	PAEC(Tn) (uJ/m3)	[218Po] pCi/L	[218Po] Bq/m3	[214Pb] pCi/L	[214Pb] Bq/m3	[214Bi] pCi/L	[214Bi] Bq/m3	[214Pb]/[218Po]	[214Bi]/[218Po]
Nov 27 90	820	0.28	5.84	0.16	3.40	44.67	1652.72	29.34	1085.71	23.04	852.51	0.657	0.516
	901	0.34	7.05	0.19	3.96	50.42	1865.48	37.20	1376.26	26.26	971.55	0.738	0.521
	1122	0.41	8.59	0.24	5.06	71.03	2627.95	47.09	1742.25	27.06	1001.31	0.663	0.381
Nov 28 90	901	0.27	5.69	0.18	3.72	44.50	1646.34	28.27	1046.03	22.53	833.73	0.635	0.506
	1001	0.27	5.67	0.16	3.28	42.07	1556.55	29.03	1074.10	21.96	812.40	0.690	0.522
	1101	0.26	5.43			28.18	1042.59	26.44	978.11	26.22	970.10	0.938	0.930
	1215	0.31	6.35			50.78	1879.04	33.60	1243.30	22.03	815.27	0.662	0.434
	1313	0.28	5.92			57.36	2122.22	31.59	1169.00	17.43	644.89	0.551	0.304
Nov 29 90	806	0.25	5.29			59.37	2196.57	31.15	1152.69	9.34	345.49	0.525	0.157
	900	0.23	4.73	0.12	2.55	41.93	1551.48	25.19	932.07	15.08	557.85	0.601	0.360
	1000	0.23	4.73	0.13	2.67	33.52	1240.30	21.91	810.80	21.87	809.21	0.654	0.652
Nov 30 90	822	0.26	5.34	0.14	3.00	53.75	1988.82	28.60	1058.12	15.12	559.35	0.532	0.281
	911	0.25	5.23	0.12	2.55	45.28	1675.26	27.79	1028.37	17.02	629.84	0.614	0.376
	1000	0.25	5.28			44.21	1635.73	27.32	1010.81	18.67	690.71	0.618	0.422
	1100	0.27	5.64			53.74	1988.49	32.18	1190.74	14.04	519.40	0.599	0.261
	1220	0.27	5.62			54.99	2034.63	27.29	1009.78	20.05	741.88	0.496	0.365
	1332	0.27	5.58			52.71	1950.29	27.98	1035.40	19.27	712.86	0.531	0.366
Dec 4 90	830	0.22	4.58	0.11	2.30	25.15	930.41	23.93	885.43	19.46	720.07	0.952	0.774
	930	0.25	5.28	0.14	2.95	26.89	994.92	26.35	975.11	24.81	917.88	0.980	0.923
	1030	0.23	4.83			38.58	1427.30	24.35	901.10	18.43	681.93	0.631	0.478
	1225	0.24	5.00			40.09	1483.15	25.76	953.15	18.31	677.32	0.643	0.457
Dec 5 90	905	0.26	5.51	0.16	3.37	39.59	1464.65	28.56	1056.61	21.22	785.11	0.721	0.536
	1000	0.26	5.51	0.12	2.52	46.67	1726.82	27.36	1012.43	20.84	770.99	0.586	0.446
	1055	0.23	4.77			34.57	1279.23	23.30	862.14	20.16	745.84	0.674	0.583
	1230	0.25	5.13			40.74	1507.30	25.90	958.19	19.58	724.52	0.636	0.481
	1314	0.26	5.41			38.05	1407.97	25.62	947.95	24.33	900.31	0.673	0.639
Dec 6 90	825	0.27	5.56	0.16	3.24	42.18	1560.55	28.96	1071.58	20.64	763.56	0.687	0.489
	925	0.24	5.09	0.14	2.85	44.91	1661.74	26.00	961.94	17.88	661.40	0.579	0.398
	1025	0.25	5.30			42.45	1570.59	26.54	982.14	20.40	754.84	0.625	0.481
	1105	0.24	5.09			48.50	1794.39	25.62	948.12	17.28	639.41	0.528	0.356
	1230	0.24	5.00			39.68	1468.16	27.31	1010.60	16.36	605.44	0.688	0.412
	1340	0.39	8.07			60.57	2241.10	42.46	1571.16	29.51	1091.70	0.701	0.487
Dec 7 90	835	0.26	5.35	0.16	3.28	40.59	1501.99	26.58	983.59	21.53	797.53	0.655	0.531
	920	0.25	5.23	0.15	3.16	42.19	1560.87	25.84	956.18	20.62	762.90	0.613	0.489
	1020	0.24	4.95			39.01	1443.42	24.94	922.94	19.05	704.93	0.639	0.488
	1110	0.24	5.03			33.61	1243.62	23.50	869.36	23.37	872.10	0.699	0.701
	1235	0.25	5.23			41.14	1522.29	27.29	1009.62	18.95	701.06	0.663	0.461
	1345	0.24	4.96			35.48	1312.67	23.90	884.34	21.59	798.72	0.674	0.608
Dec 10 90	900	0.34	7.01	0.15	3.16	57.58	2130.32	38.22	1414.01	22.50	832.67	0.664	0.391
	930	0.37	7.64	0.17	3.60	45.37	1678.55	38.71	1432.31	33.28	1231.18	0.853	0.733

Cont.

Table 3 - cont.

	1035	0.30	6.21			61.08	2260.03	32.59	1205.84	18.84	697.11	0.534	0.308
	1115	0.26	5.49			37.81	1398.80	28.09	1039.15	22.09	817.36	0.743	0.584
	1250	0.25	5.26			56.15	2077.53	28.49	1053.97	13.52	500.27	0.507	0.241
	1325	0.32	6.74			56.67	2096.82	34.37	1271.82	24.39	902.46	0.607	0.430
Dec 13 90	856	0.23	4.84	0.17	3.61	51.96	1922.62	24.32	899.85	14.93	552.46	0.468	0.287
	1000	0.29	6.03	0.14	2.98	50.41	1865.26	29.99	1109.76	22.93	848.43	0.595	0.455
	1101	0.29	5.94			52.43	1940.00	32.50	1202.37	17.89	661.86	0.620	0.341
	1225	0.23	4.72			37.32	1380.68	22.31	825.56	20.16	745.97	0.598	0.540
	1315	0.22	4.61			47.25	1748.18	23.80	880.63	13.99	517.81	0.504	0.296
Dec 14 90	845	0.24	4.94	0.15	3.20	46.53	1721.69	25.79	954.30	15.74	582.53	0.554	0.338
	945	0.27	5.67	0.17	3.54	48.35	1788.85	28.00	1036.18	21.60	799.09	0.579	0.447
	1045	0.24	4.99			32.58	1205.33	24.41	903.12	22.03	815.27	0.749	0.676
	1300	0.28	5.82			46.23	1710.59	29.44	1089.16	22.18	820.64	0.637	0.480
Dec 17 90	840	0.33	6.85	0.15	3.08	39.82	1473.21	33.52	1240.16	31.67	1171.67	0.842	0.795
	1020	0.30	6.30			34.54	1277.90	33.17	1227.23	26.56	982.65	0.960	0.769
	1110	0.30	6.22			59.07	2185.52	32.64	1207.69	19.42	718.67	0.553	0.329
	1238	0.41	8.50			58.33	2158.37	45.94	1699.61	30.94	1144.63	0.787	0.530
	1352	0.29	5.97			52.82	1954.36	31.30	1158.01	19.74	730.26	0.593	0.374
Dec 18 90	840	0.26	5.41	0.21	4.33	42.01	1554.33	27.63	1022.13	20.57	761.00	0.658	0.490
	950	0.27	5.61			48.49	1794.23	29.70	1098.98	18.53	685.58	0.613	0.382
	1100	0.25	5.16			51.76	1915.20	26.40	976.66	16.31	603.51	0.510	0.315
	1245	1.20	24.88			154.38	5712.03	123.30	4562.13	110.18	4076.84	0.799	0.714
	1320	1.06	21.98			143.27	5300.95	108.70	4022.06	95.75	3542.73	0.759	0.668
Dec 19 90	832	0.24	5.01			55.32	2047.00	25.17	931.29	15.05	557.03	0.455	0.272
	935	0.23	4.88	0.16	3.25	43.87	1623.32	23.73	878.11	18.53	685.60	0.541	0.422
	1035	0.22	4.48			42.62	1576.83	20.71	766.42	17.84	660.03	0.486	0.419
	1130	0.21	4.33			31.58	1168.52	19.63	726.18	20.33	752.28	0.621	0.644
	1245	0.23	4.78			47.69	1764.54	23.83	881.78	15.98	591.10	0.500	0.335
Dec 20 90	820	0.66	13.83	0.22	4.49	109.60	4055.34	69.81	2583.13	52.97	1960.03	0.637	0.483
	900	0.53	11.05	0.22	4.60	79.29	2933.61	54.05	1999.83	47.00	1738.89	0.682	0.593
	955	0.40	8.29			54.10	2001.61	39.61	1465.62	37.99	1405.53	0.732	0.702
	1100	0.32	6.70			56.78	2100.76	33.99	1257.46	24.37	901.74	0.599	0.429
	1230	0.26	5.34			46.81	1731.80	27.18	1005.74	18.88	698.61	0.581	0.403

Table 4 - Summary of MMAD and AMAD data obtained with the cascade impactors.

U/G Work STANLEIGH, Nov,Dec/90

Instrument	Date (1990)	Substrate Material	Type of Dust	MMAD (um)	Og	AMAD (LLRD) (um)	Og	AMAD (TnP) (um)	Og	Remarks
Sierra 210	Nov. 29,30	GF	Stanleigh	2.21	3.44	1.81	5.32	0.26	2.70	
Marple 290	Nov. 29,30	SS	Stanleigh	1.83	11.67	2.54	8.82			
Sierra 210	Dec. 4,5,6	GF	Stanleigh	2.28	4.66	4.30	3.74	0.25	3.18	
Marple 290	Dec. 4,5,6	SS	Stanleigh	2.87	8.40	5.62	6.32			
Sierra 210	Dec. 7,10	GF	Stanleigh	2.47	4.33	3.00	4.77			
Marple 290	Dec. 7,10	SS	Stanleigh	5.06	7.26	5.29	3.99			
Sierra 210	Dec. 13,14,17	GF	Stanleigh	3.72	2.87	5.19	3.26	0.21	3.60	
Marple 290	Dec. 13,14,17	SS	Stanleigh	4.48	2.70	7.10	2.55			
Sierra 210	Dec. 18,19,20	GF	Stanleigh	3.48	2.76	4.97	3.06			
Marple 290	Dec. 18,19,20	SS	Stanleigh	5.39	2.38	8.14	2.42			

GF = glass fibre
SS = stainless steel

Table 5 - Data corresponding to the PADs (CEA track-etch dosimeters).

CEA DOSIMETERS

FILM #	DATE (1990)	TIME ON	TIME OFF	TOTAL TIME MINUTES	TOTAL TIME HOURS	Q (1)	Q (2)	Q (AVG)	AIR VOLUME (l)	DUST MASS (ug)	DUST CONC (ug/m3)	DPM	ACTIVITY (mBq/m3)	REMARKS
13	NOV 29	8.1	14.3	380	6.33	3.31	3.15	3.23	20.46	0.41	3.27	0.484	64.40	STANLEIGH U/G
13	NOV 30	8.13	14.15	362	6.03	3.47	2.75	3.11	18.76					
13	DEC 4	8.15	14.25	370	6.17	3.2	2.8	3	18.50					
13	DEC 5	9	14.25	325	5.42	3.3	2.82	3.06	16.58					
13	DEC 6	8.16	14.28	372	6.20	3.15	2.6	2.875	17.83					
13	DEC 7	8.27	14.25	358	5.97	3.05	2.48	2.765	16.50					
13	DEC 10	8.46	14.2	334	5.57	3.15	2.83	2.99	16.64					
									125.26					
14	NOV 29	8.1	14.3	380	6.33	3.35	3.3	3.325	21.06	0.36	2.69	0.742	92.54	STANLEIGH U/G
14	NOV 30	8.13	14.15	362	6.03	3.31	3.1	3.205	19.34					
14	DEC 4	8.15	14.25	370	6.17	3.17	3.1	3.135	19.33					
14	DEC 5	9	14.25	325	5.42	3.15	2.95	3.05	16.52					
14	DEC 6	8.16	14.28	372	6.20	3.42	3.15	3.285	20.37					
14	DEC 7	8.27	14.25	358	5.97	3.31	2.97	3.14	18.74					
14	DEC 10	8.46	14.2	334	5.57	3.34	3.23	3.285	18.29					
									133.64					
15	DEC 13	8.39	14.26	347	5.78	3.06	3.05	3.055	17.67	0.53	4.93	2.62	406.39	STANLEIGH U/G
15	DEC 14	8.35	14.2	345	5.75	3.2	2.75	2.975	17.11					
15	DEC 17	8.24	14.26	362	6.03	3.18	2.72	2.95	17.80					
15	DEC 18	8.26	14.25	359	5.98	3.06	2.7	2.88	17.23					
15	DEC 19	8.15	14.26	371	6.18	3.12	3.07	3.095	19.14					
15	DEC 20	8.15	14.27	372	6.20	3.22	2.75	2.985	18.51					
									107.45					
16	DEC 13	8.39	14.26	347	5.78	2.5	3.24	2.87	16.60	0.63	5.68	2.86	429.70	STANLEIGH U/G
16	DEC 14	8.35	14.2	345	5.75	3.1	3.05	3.075	17.68					
16	DEC 17	8.24	14.26	362	6.03	3.15	3.18	3.165	19.10					
16	DEC 18	8.26	14.25	359	5.98	3.19	2.99	3.09	18.49					
16	DEC 19	8.15	14.26	371	6.18	3.35	3.15	3.25	20.10					
16	DEC 20	8.15	14.27	372	6.20	3.1	3.02	3.06	18.97					
									110.93					

Table 6 - Dust and LLRD concentrations for different sampling instruments and sampling periods.

STANLEIGH

DATE (1990)	DUST CONCENTRATION (ug/m3) TOTAL DUST	NYLON CYCLONE	SIERRA 210	HARPLE 290	MINIRAM	LLRD CONCENTRATION (mBq/m3) TOTAL DUST	NYLON CYCLONE	SIERRA 210	HARPLE 290
NOV.29,30	1.22	0.44	0.91	0.81		26	10	31	39
DEC.4	1.58				0.208	111			
DEC.5	0.80				0.261	52			
DEC.6	1.38	0.51	1.02	0.90	0.095	87	23	85	57
DEC.7	1.08				0.092	110			
DEC.10	3.17	0.47	0.97	1.03	0.161	300	18	63	59
DEC.13	3.33				0.369	263			
DEC.14	4.42				0.691	688			
DEC.17	3.44	0.79	2.09	1.46	0.133	44	40	179	145
DEC.18	2.40				0.274	43			
DEC.19	2.35				0.703	628			
DEC.20	2.14	0.65	1.94	1.58	0.591	491	53	134	148

DATE (1990)	DUST CONCENTRATION (ug/m3) TOTAL DUST	NYLON CYCLONE	SIERRA 210	HARPLE 290	MINIRAM	LLRD CONCENTRATION (mBq/m3) TOTAL DUST	NYLON CYCLONE	SIERRA 210	HARPLE 290
NOV.29,30	1.22	0.44	0.91	0.81	—	26	10	31	39
DEC. 4,5,6	1.27	0.51	1.02	0.90	0.19	85	23	85	57
DEC. 7,10	2.09	0.47	0.97	1.03	0.13	202	18	63	59
DEC. 13,14,17	3.72	0.79	2.09	1.46	0.46	326	40	179	145
DEC. 18,19,20	2.29	0.65	1.94	1.58	0.32	391	53	134	148

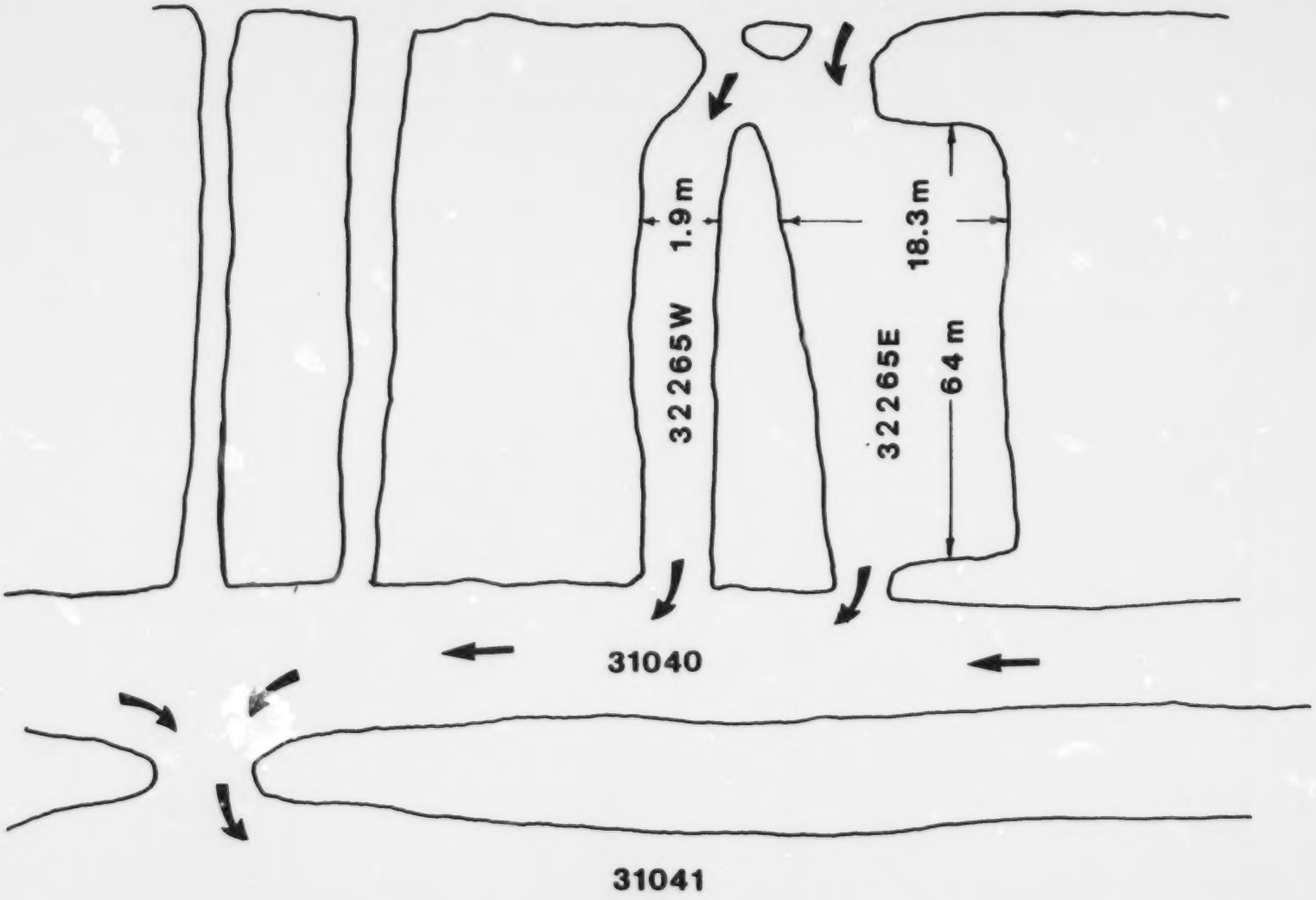
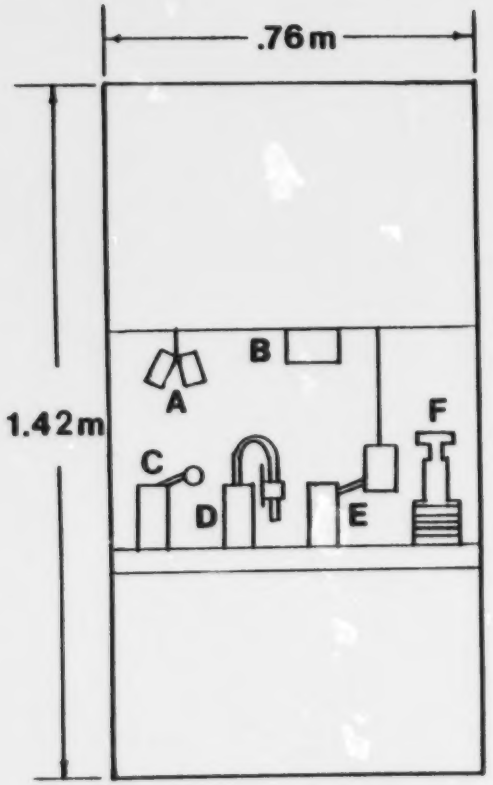
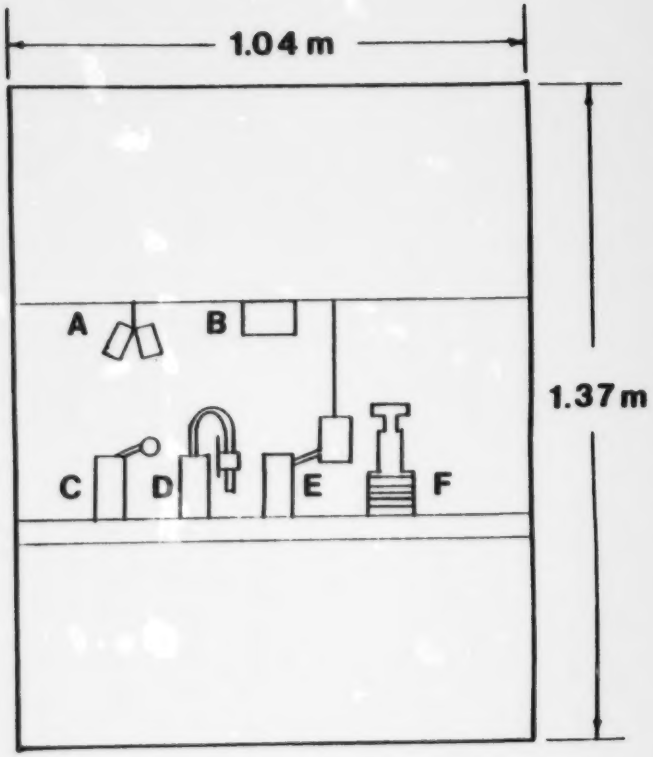


Fig. 1a - Underground location where measurements were conducted.
Arrows indicate direction of airflow.



32265W



32265 E

A - CEA Dos
B - Mini Ram
C - Total Dust
D - Nylon Cyclone
E - Marple 290
F - Sierra 210

Fig. 1b - Positions of the instruments at the exit (rectangular openings) of the stopes.

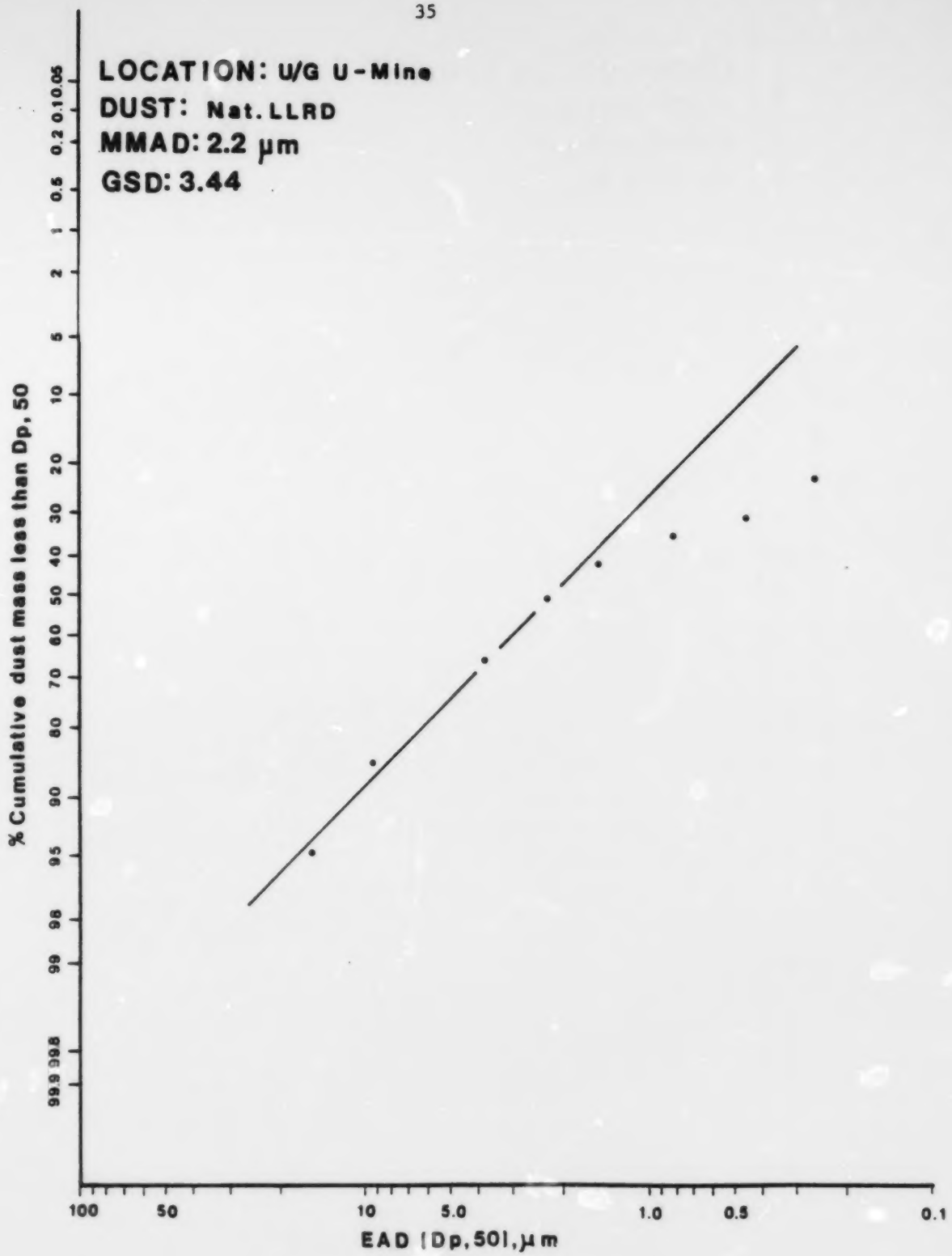


Fig. 2 - Percentage cumulative dust mass versus EAD (Nov. 29th and 30th) for the Sierra 210.

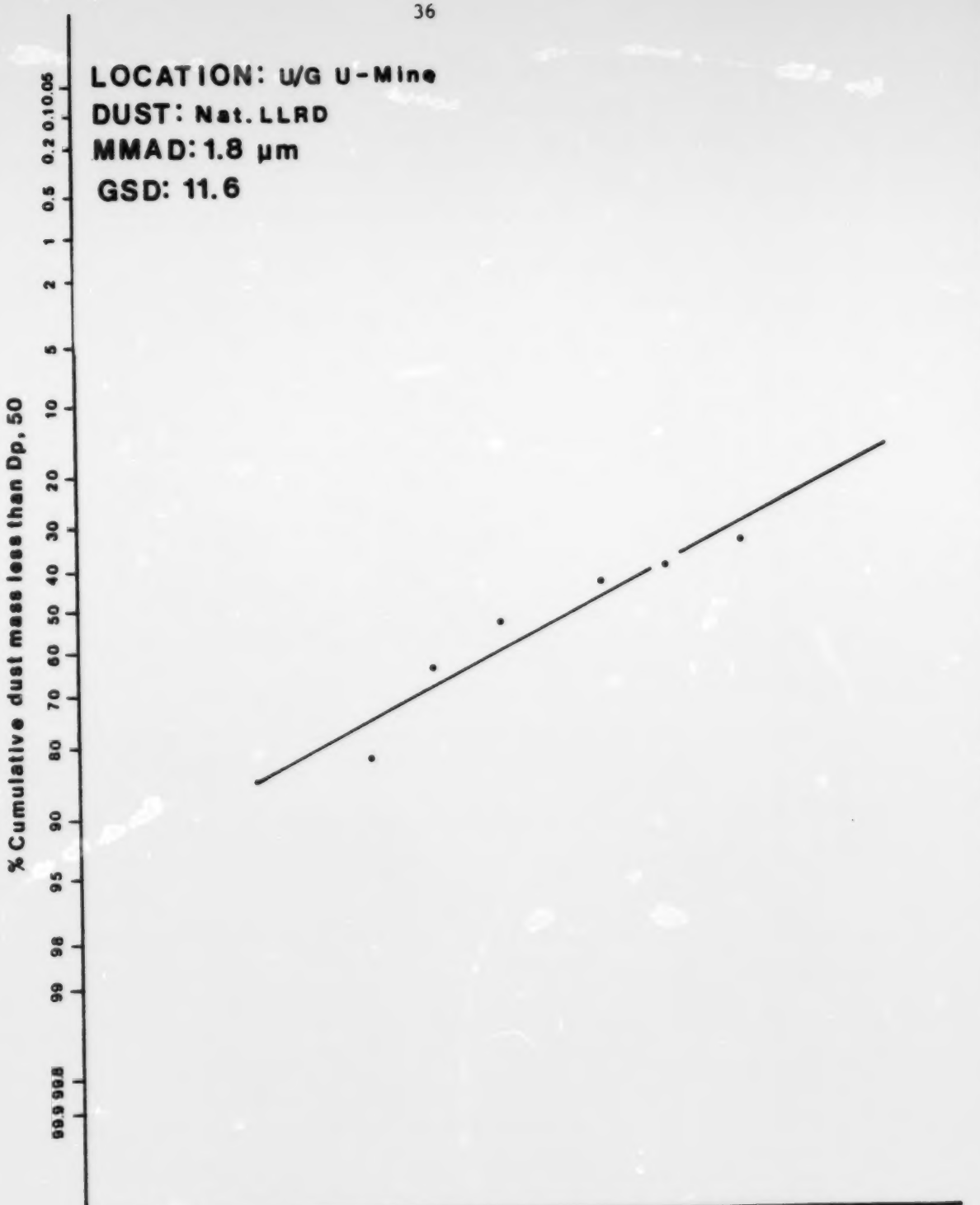

LOCATION: U/G U-Mine
DUST: Nat. LLRD
MMAD: 1.8 µm
GSD: 11.6
% Cumulative dust mass less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 3 - Percentage cumulative dust mass versus EAD (Nov. 29th and 30th) for the Marple 290.

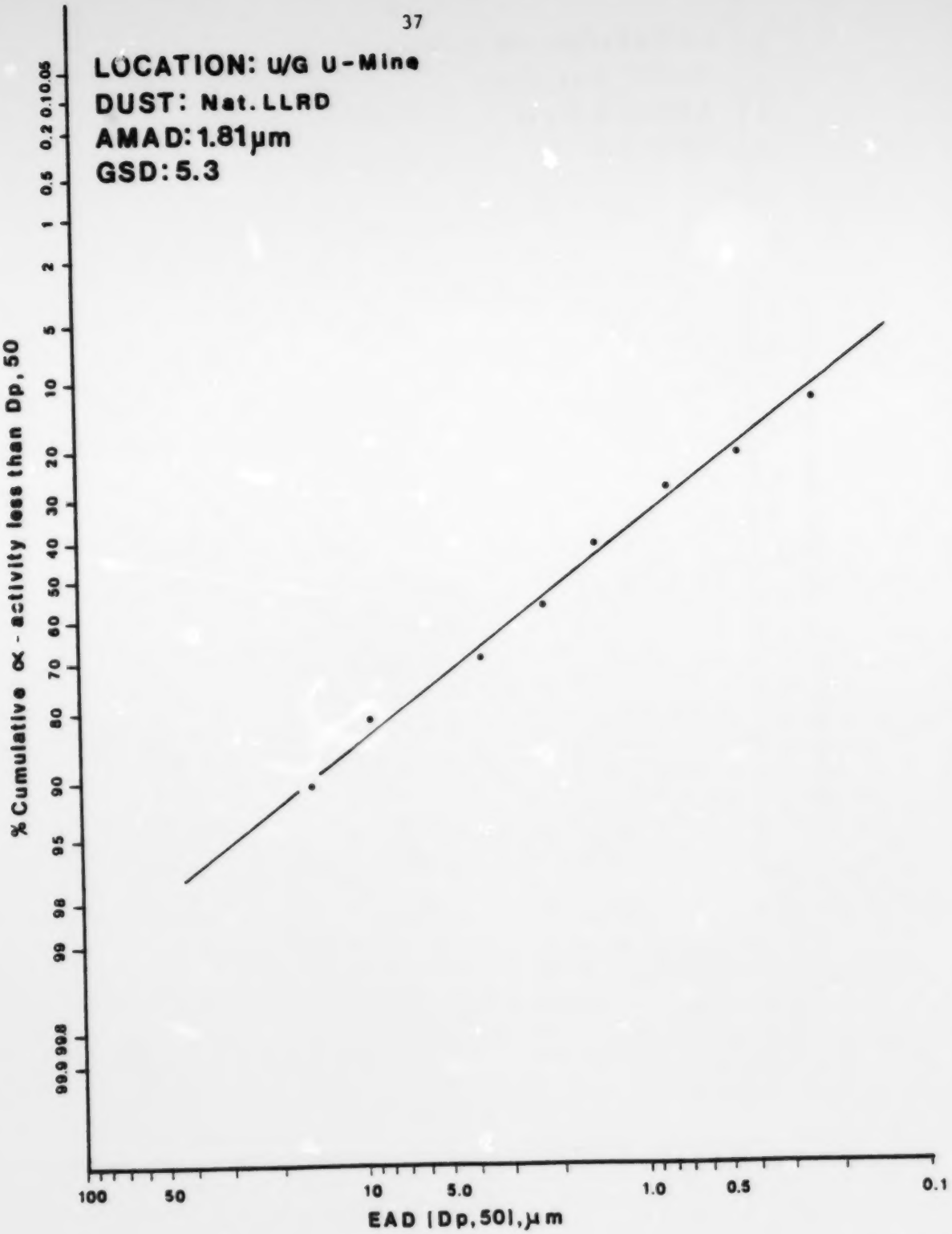

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 1.81μm
GSD: 5.3
% Cumulative α - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), μm

Fig. 4 - Percentage cumulative α-particle activity versus EAD (Nov. 29th and 30th) for the Sierra 210.

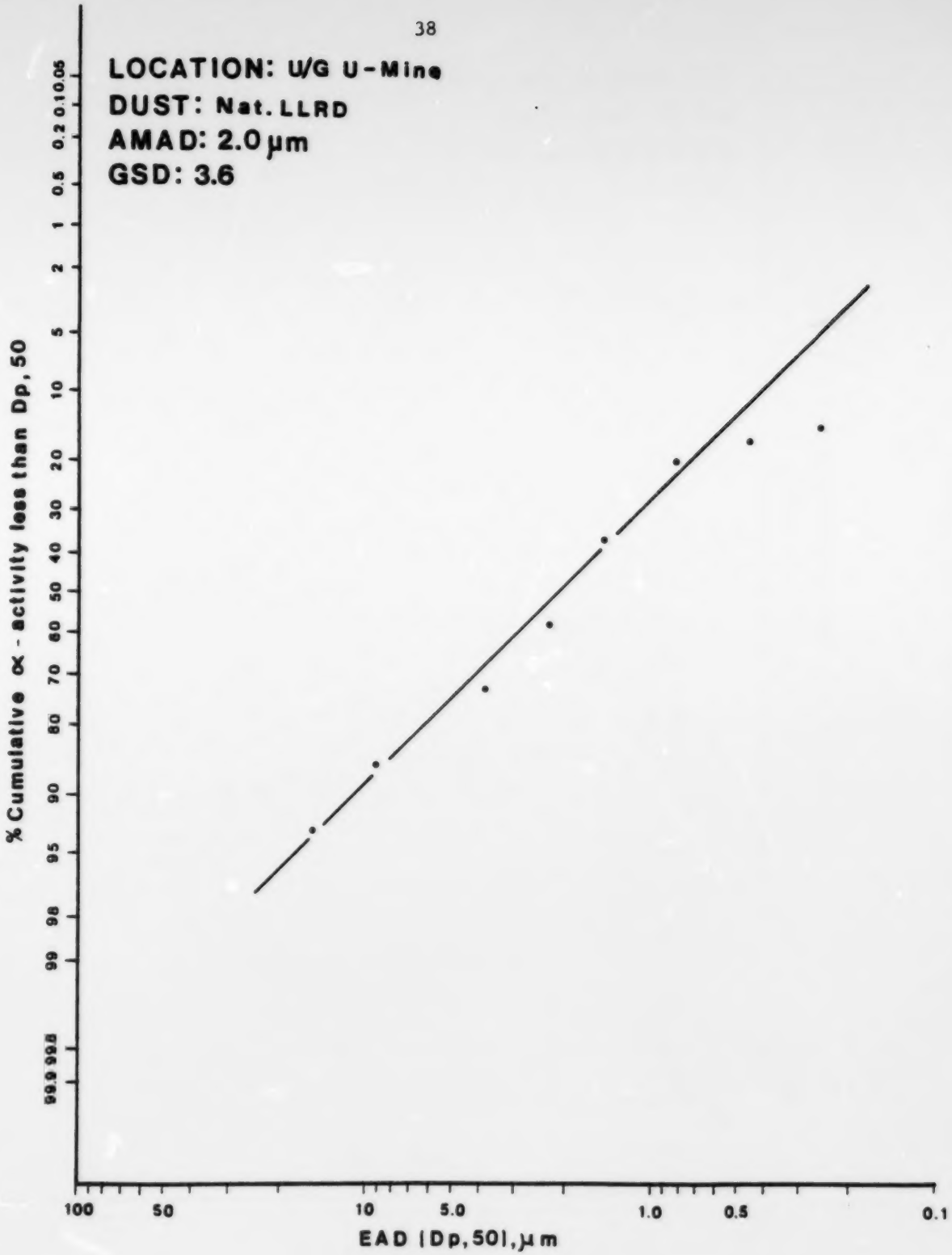


Fig. 5 - Percentage cumulative α-particle activity versus EAD (Nov. 29th and 30th) for the Sierra 210 (background substrate correction).

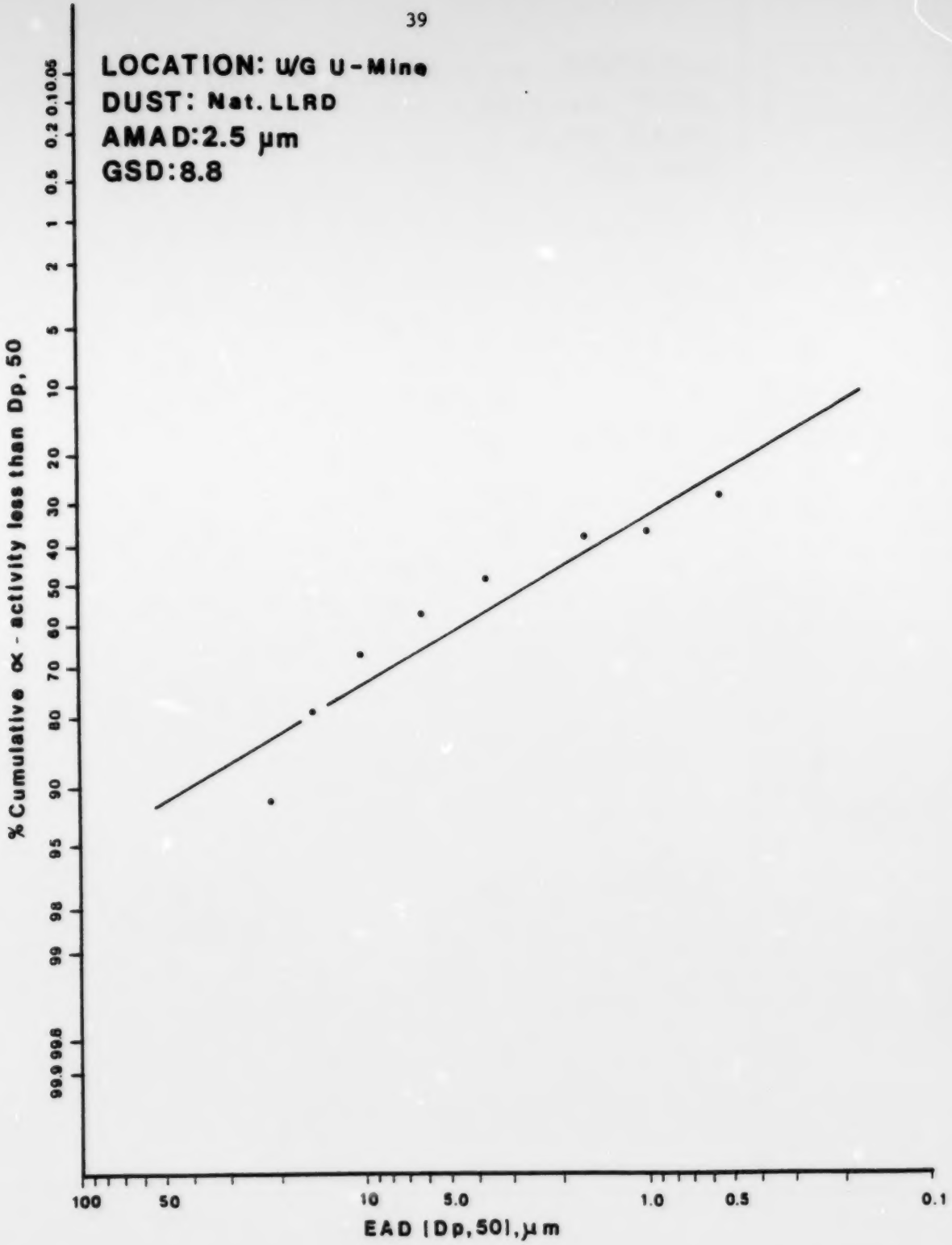

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD:2.5 µm
GSD:8.8
% Cumulative α - activity less than Dp,50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 6 - Percentage cumulative α-particle activity versus EAD (Nov. 29th and 30th) for the Marple 290.

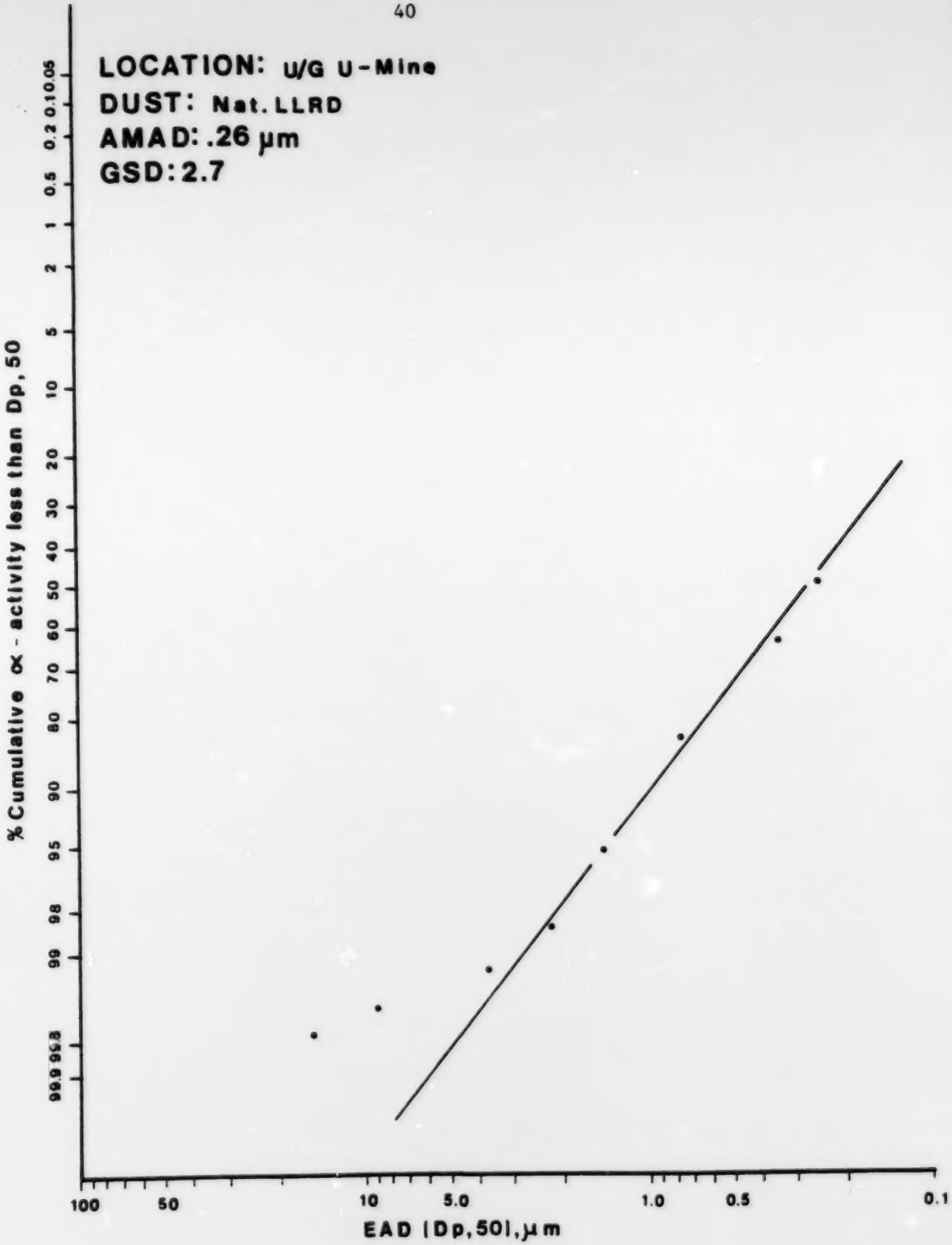

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: .26 µm
GSD: 2.7
% Cumulative α - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 7 - Percentage cumulative α-particle activity (^{220}Rn progeny) for the Sierra 210 (Nov. 29th and 30th).

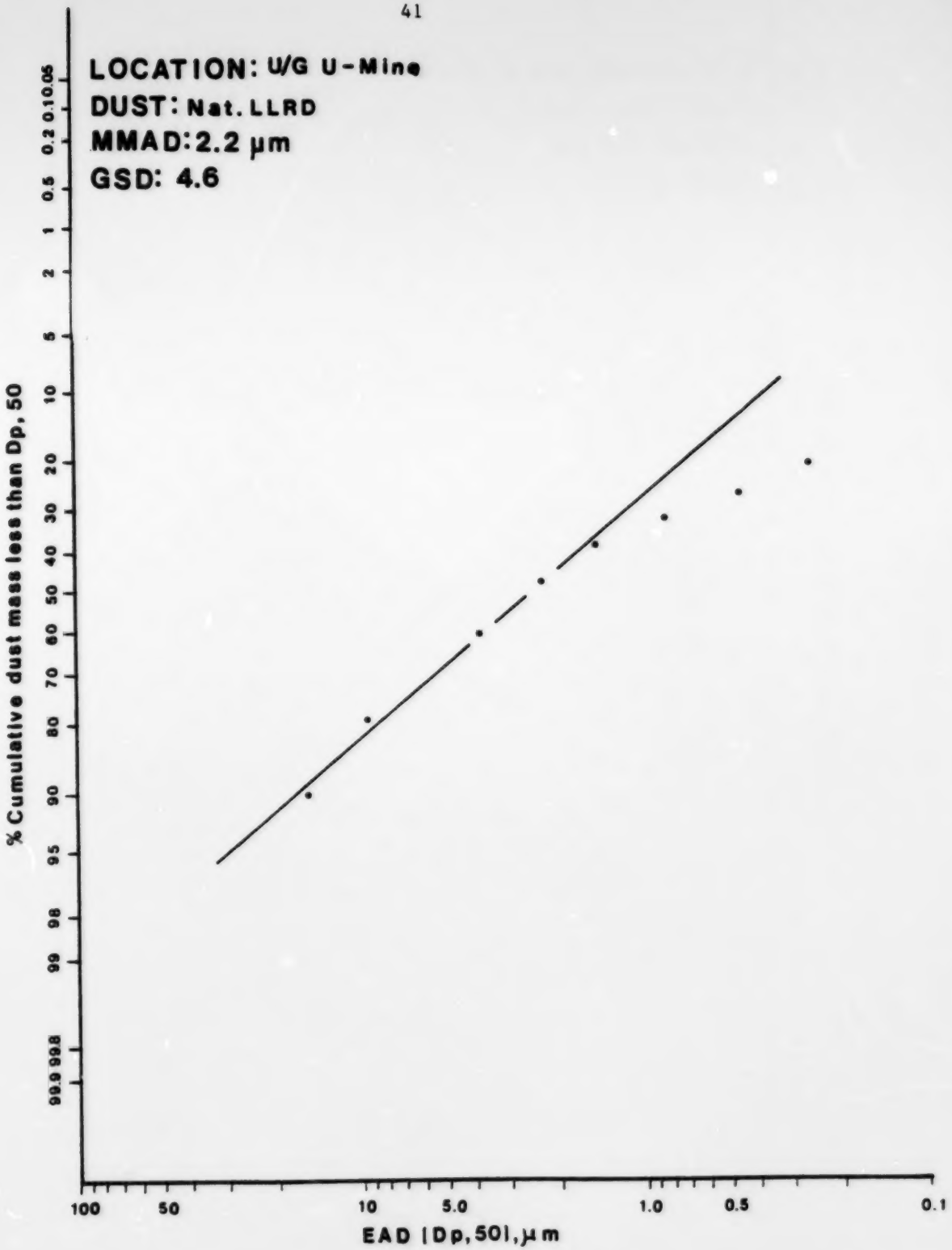

LOCATION: U/G U-Mine
DUST: Nat. LLRD
MMAD: 2.2 µm
GSD: 4.6
% Cumulative dust mass less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 8 - Percentage cumulative dust mass versus EAD (Dec. 4th, 5th and 6th) for the Sierra 210.

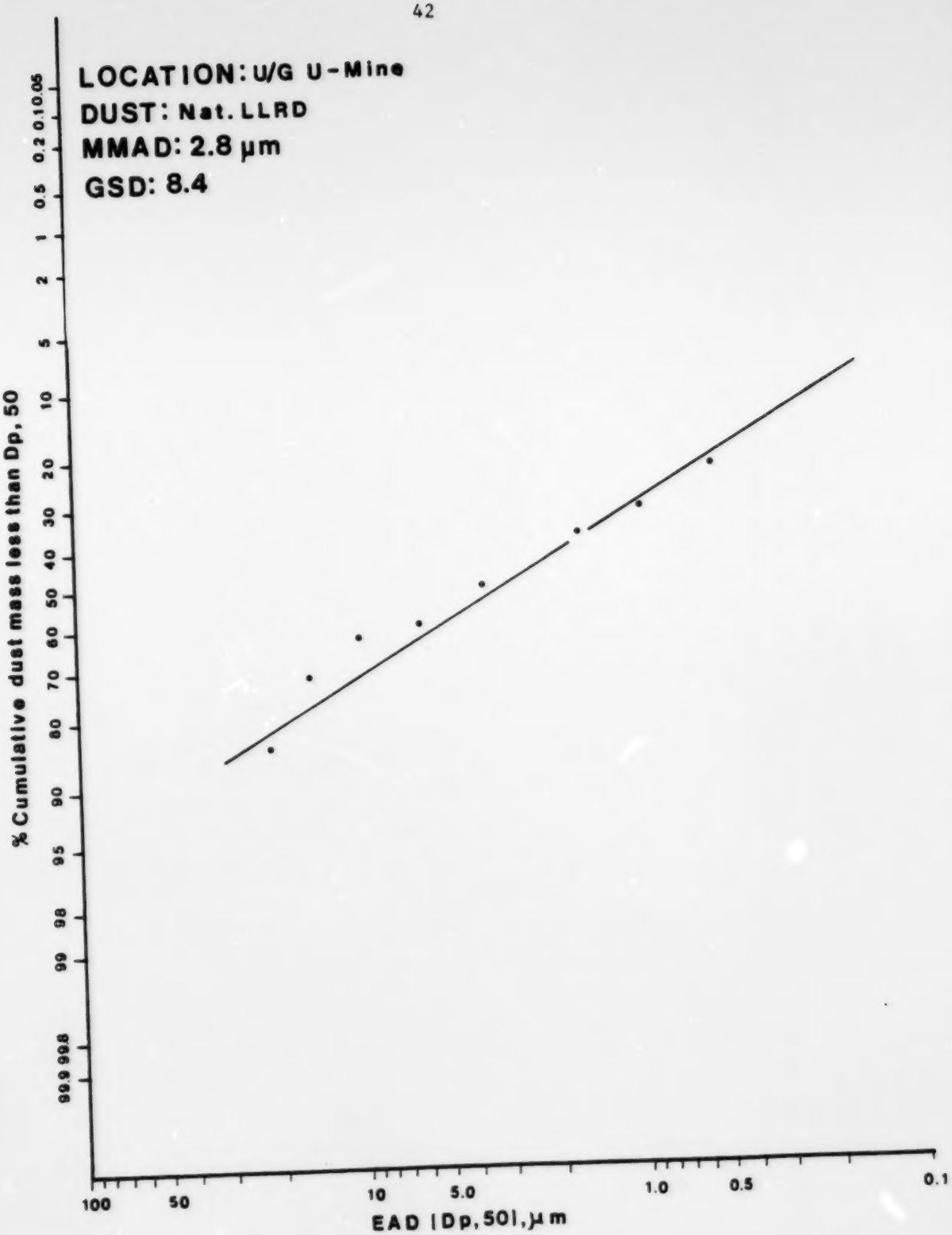

LOCATION: U/G U-Mine
DUST: Nat. LLRD
MMAD: 2.8 µm
GSD: 8.4
% Cumulative dust mass less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), µm

Fig. 9 - Percentage cumulative dust mass versus EAD (Dec. 4th, 5th and 6th) for the Marple 290.

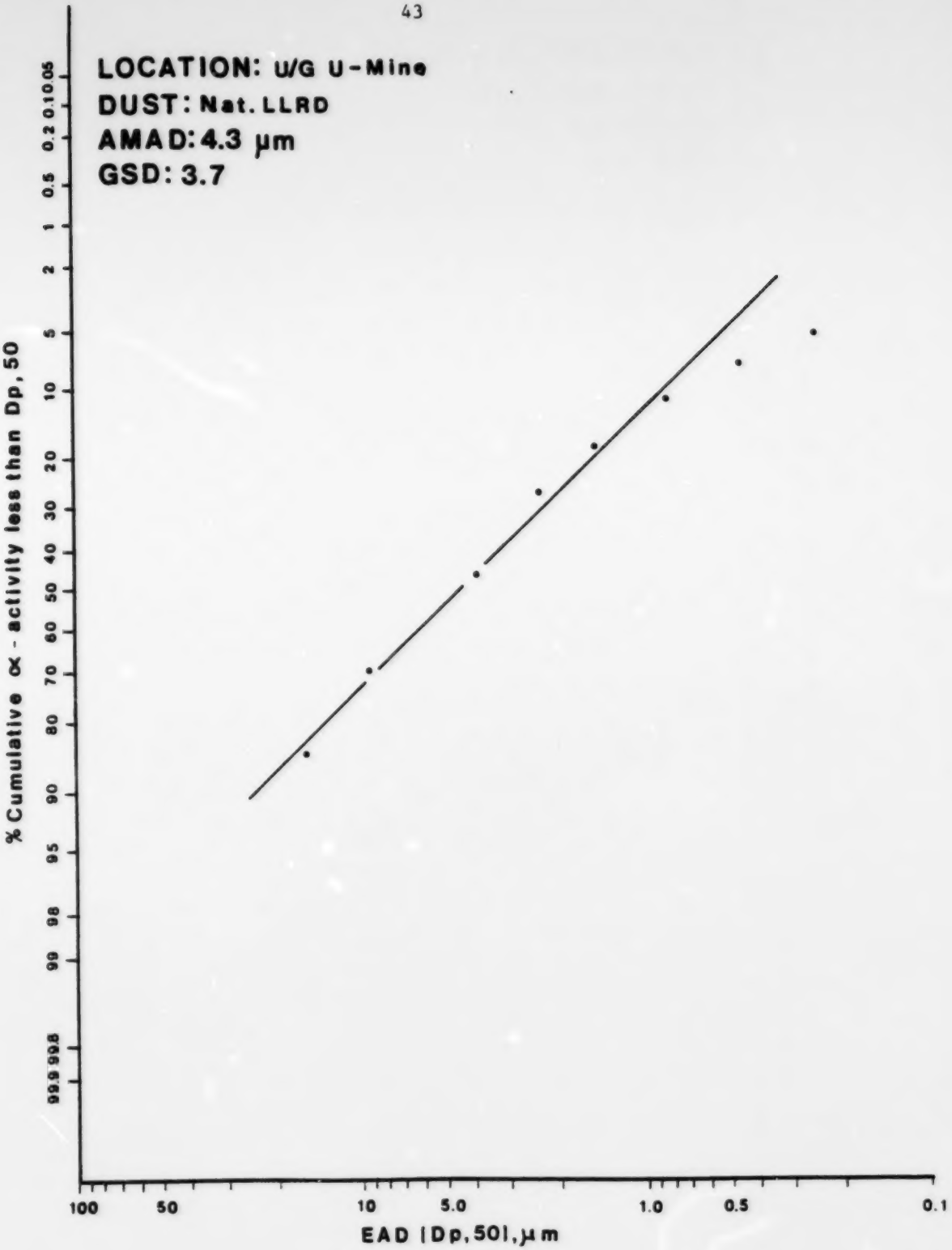

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 4.3 µm
GSD: 3.7
% Cumulative α - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), µm

Fig. 10 - Percentage cumulative α-particle activity versus EAD (Dec. 4th, 5th and 6th) for the Sierra 210.

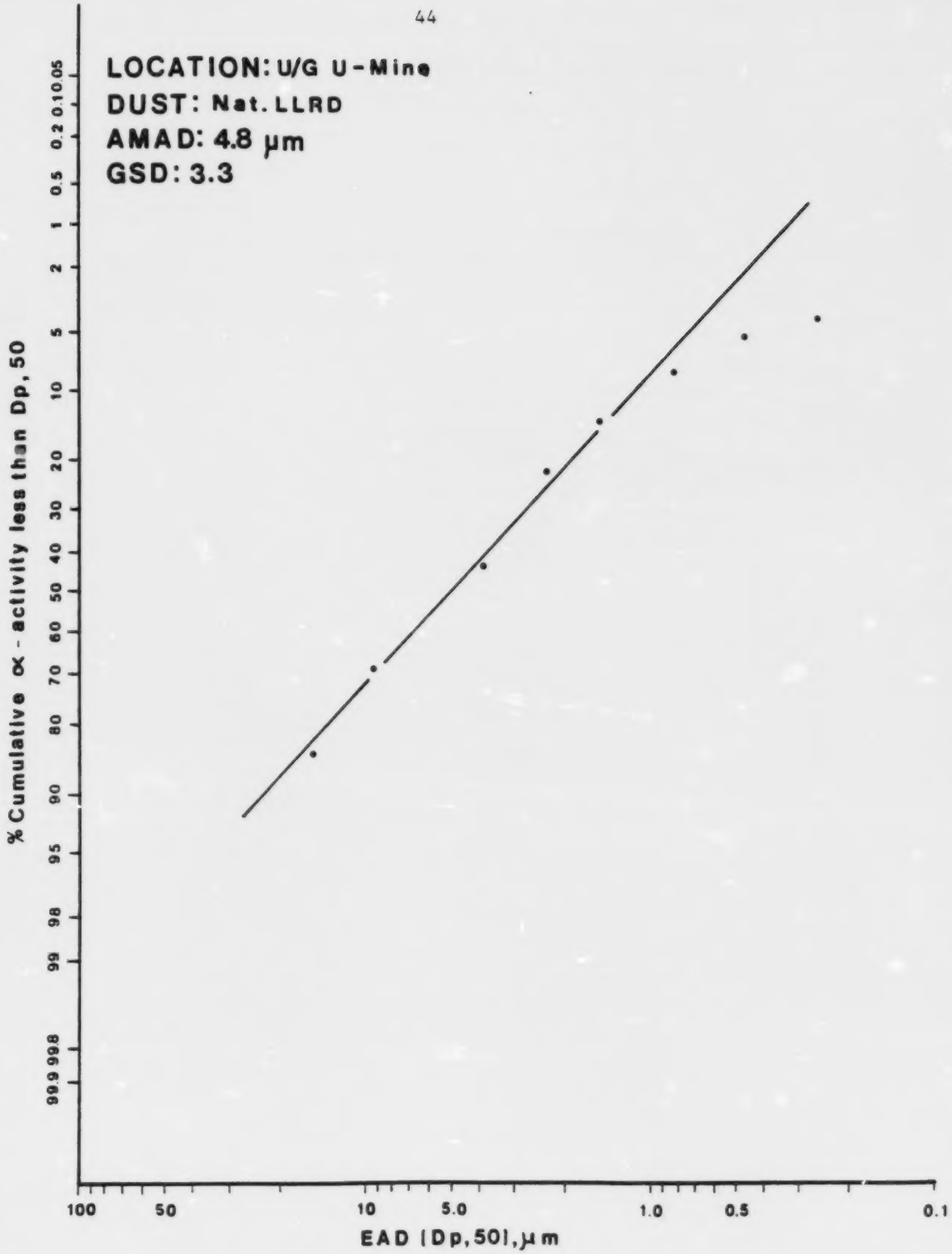

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 4.8 µm
GSD: 3.3
% Cumulative α - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), µm

Fig. 11 - Percentage cumulative α-particle activity versus EAD (Dec. 4th, 5th and 6th) for the Sierra 210 (substrate background correction.

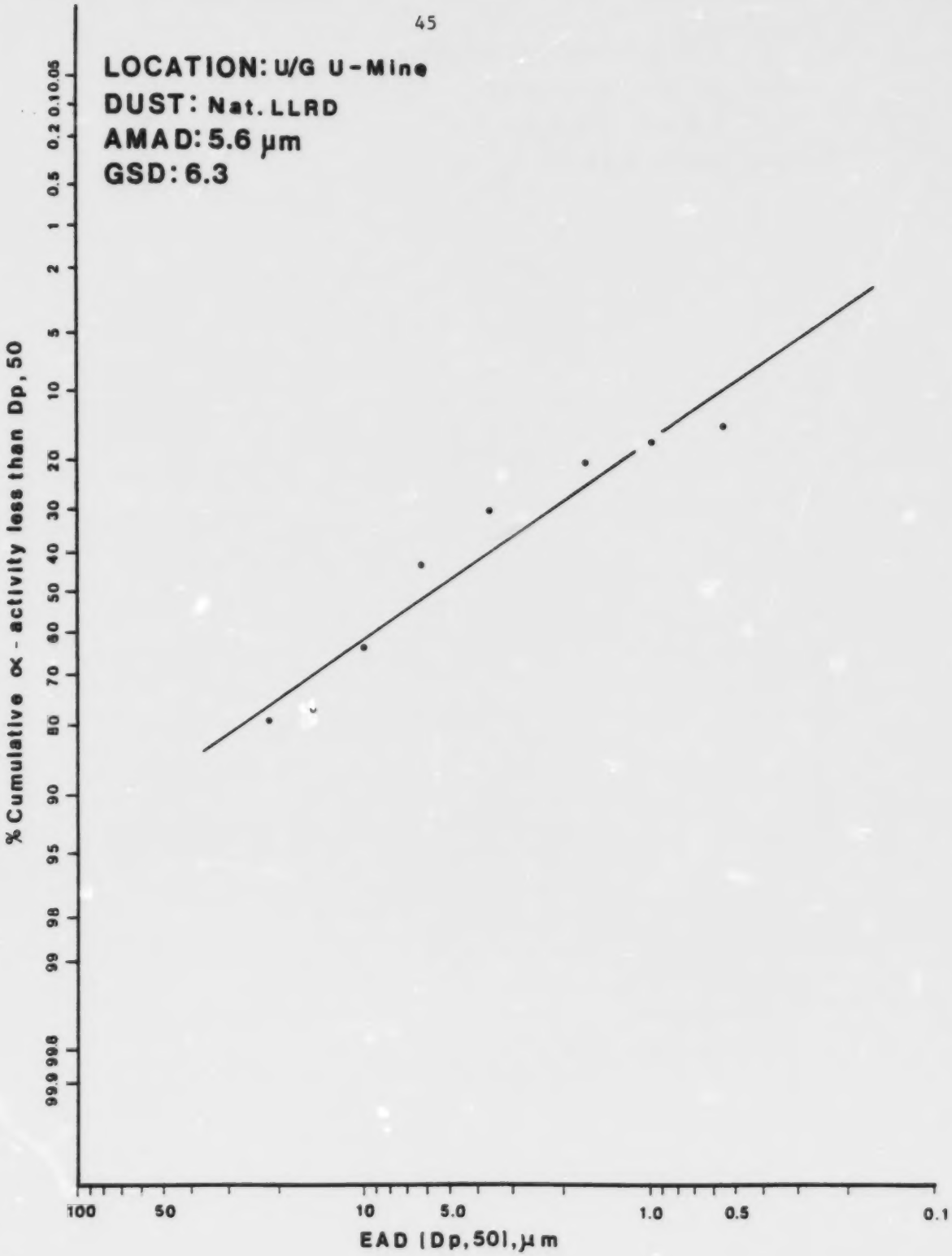

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 5.6 μm
GSD: 6.3
% Cumulative α - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), μm

Fig. 12 - Percentage cumulative α-particle activity versus EAD (Dec. 4th, 5th and 6th) for the Marple 290.

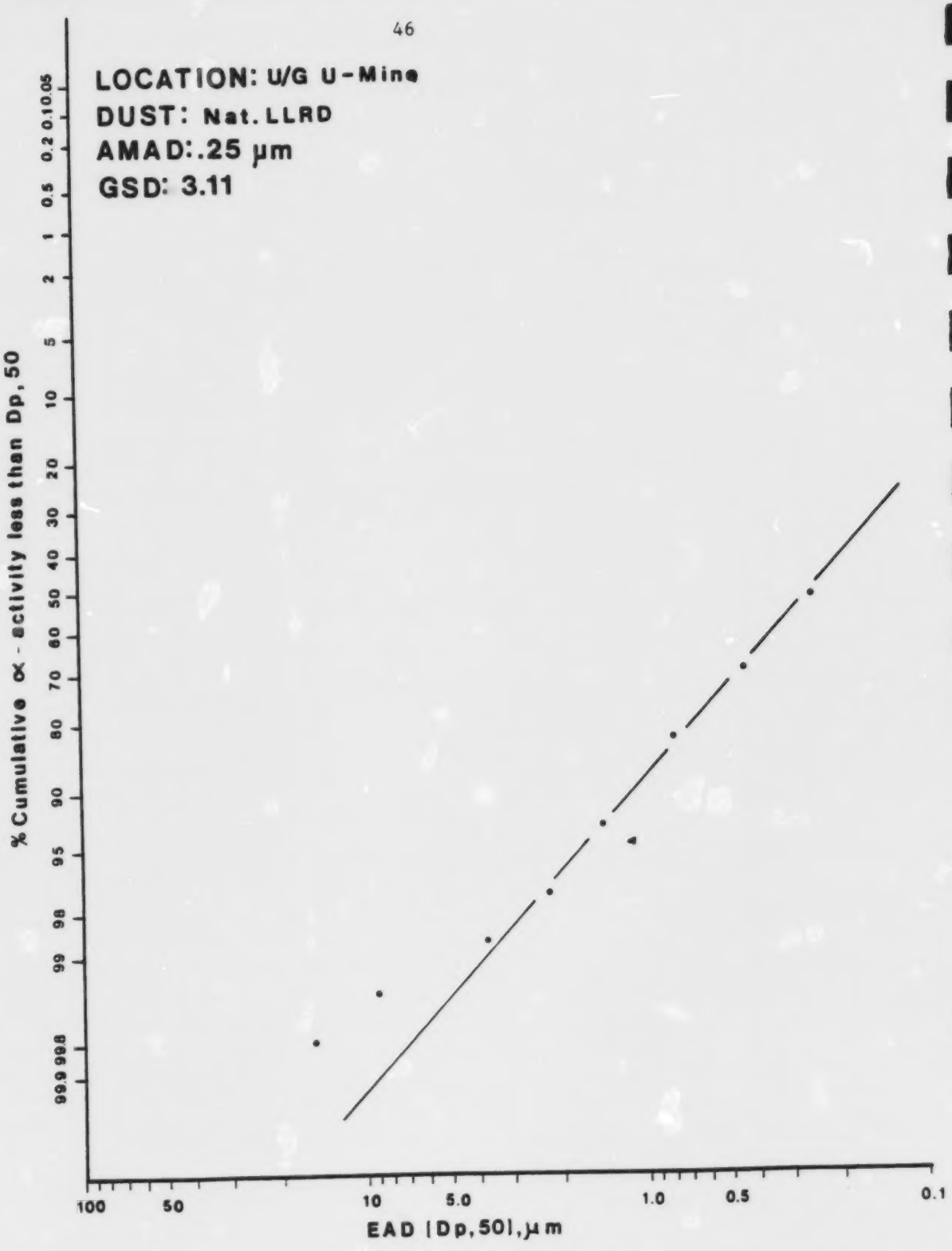

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: .25 µm
GSD: 3.11
% Cumulative ∝ - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), µm

Fig. 13 - Percentage cumulative α-particle activity versus EAD (^{220}Rn progeny) for the Sierra 210 (Dec. 4th, 5th and 6th).

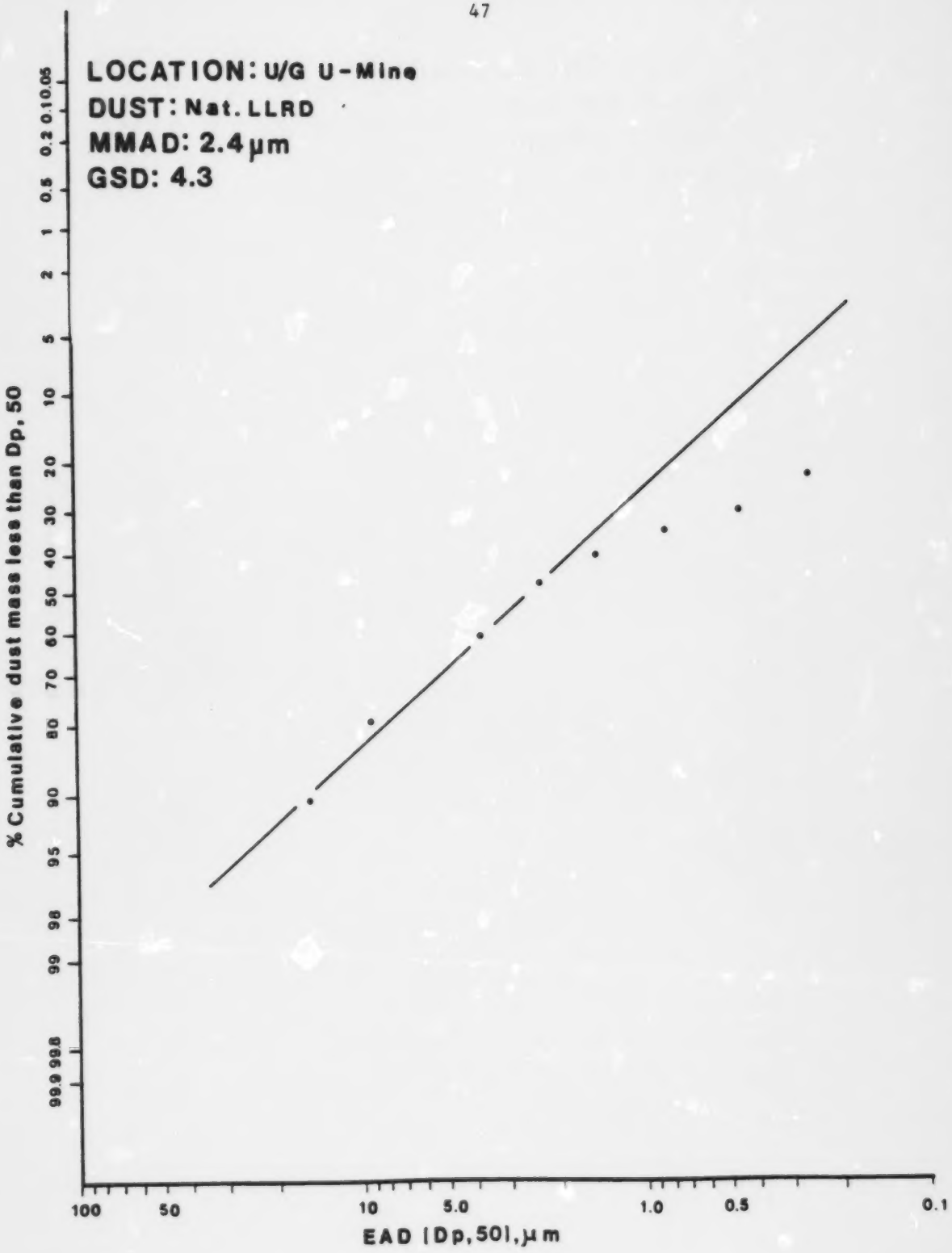

LOCATION: U/G U-Mine
DUST: Nat. LLRD
MMAD: 2.4 µm
GSD: 4.3
% Cumulative dust mass less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 14 - Percentage cumulative dust mass versus EAD (Dec. 7th and 10th) for the Sierra 210.

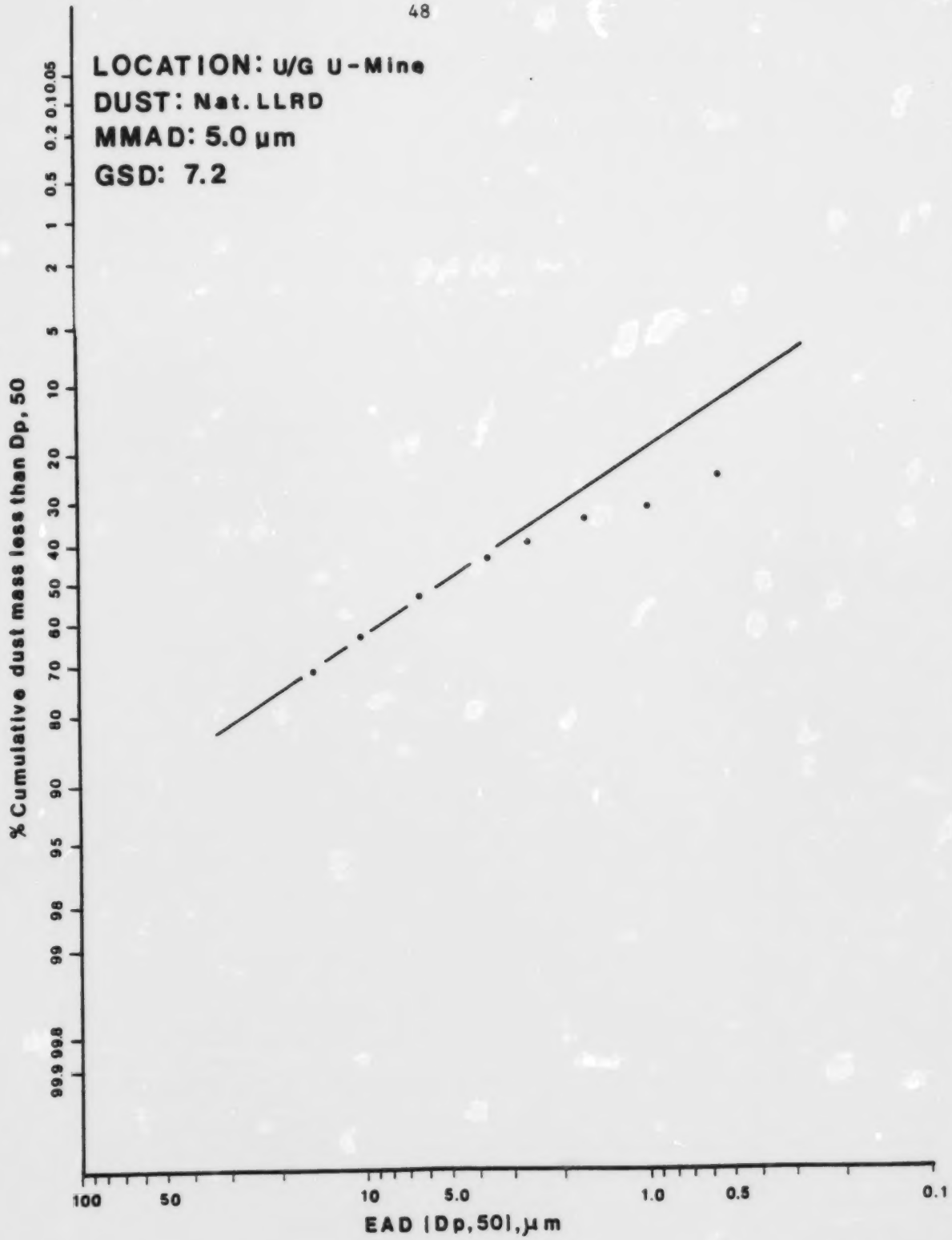

LOCATION: U/G U-Mine
DUST: Nat. LLRD
MMAD: 5.0 µm
GSD: 7.2
% Cumulative dust mass less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 15 - Percentage cumulative dust mass versus EAD (Dec. 7th and 10th) for the Marple 290.

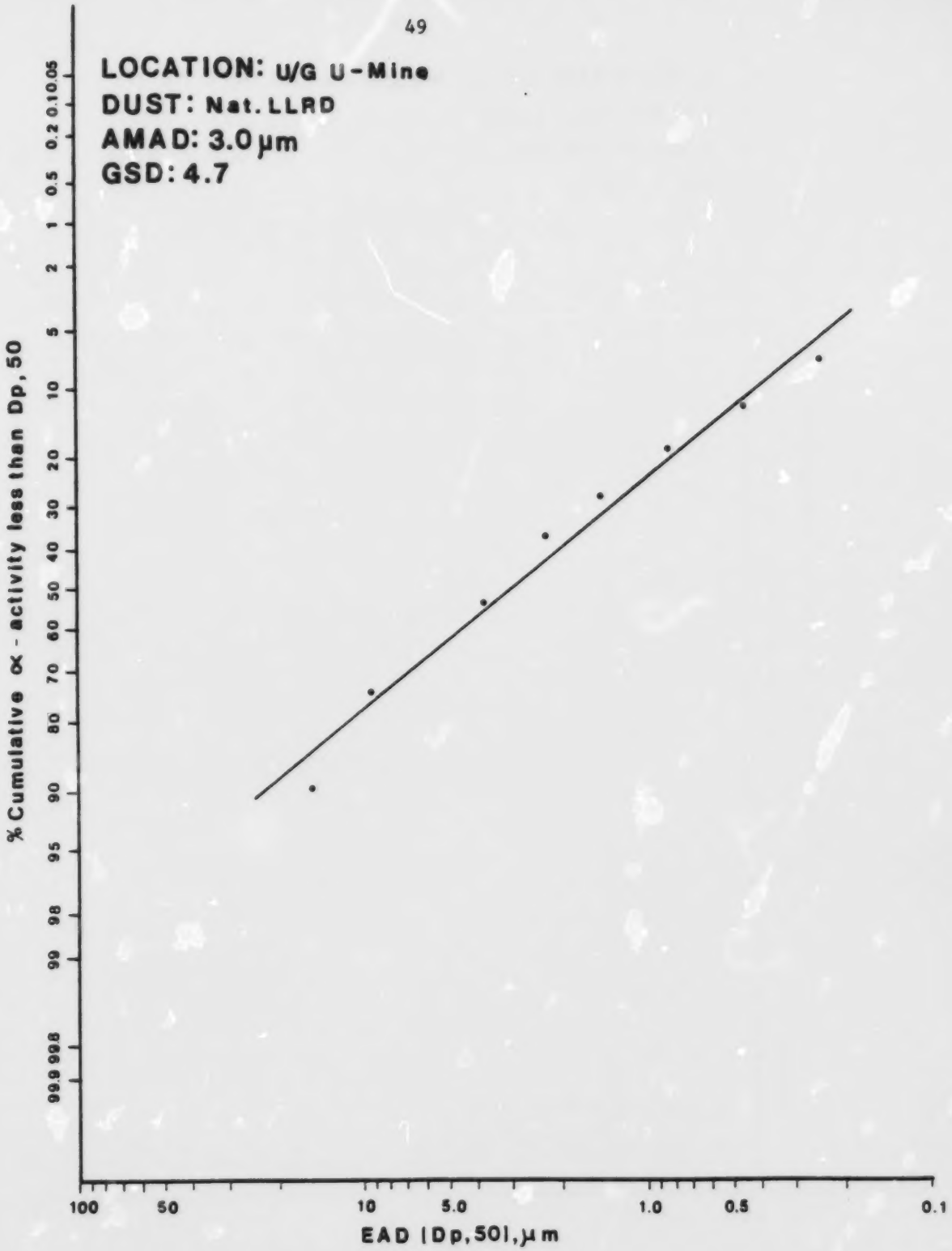

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 3.0 µm
GSD: 4.7
% Cumulative α - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), µm

Fig. 16 - Percentage cumulative α-particle activity versus EAD (Dec. 7th and 10th) for the Sierra 210.

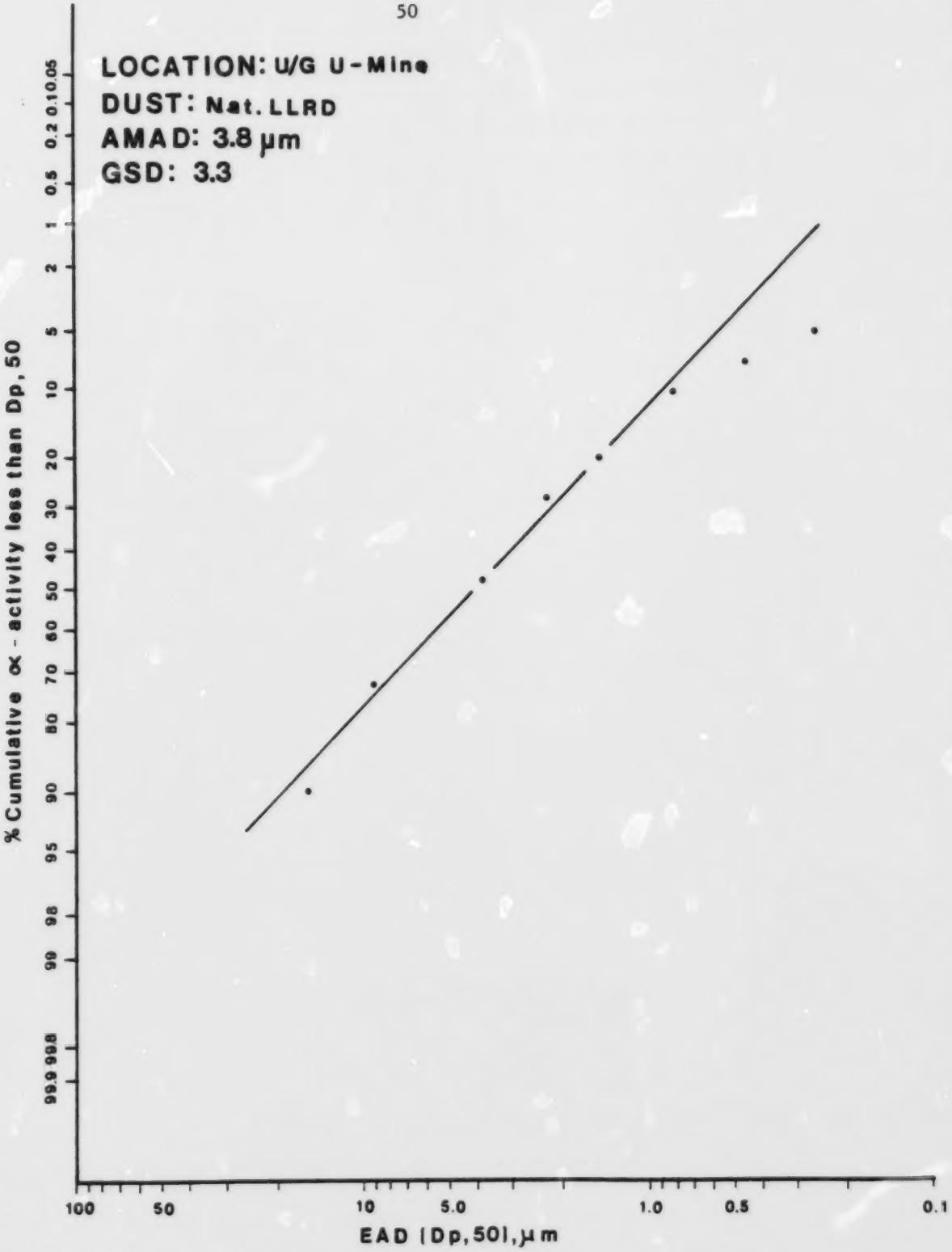


Fig. 17 - Percentage cumulative α-particle activity versus EAD (Dec. 7th and 10th) for the Sierra 210 (corrected for substrate's background).

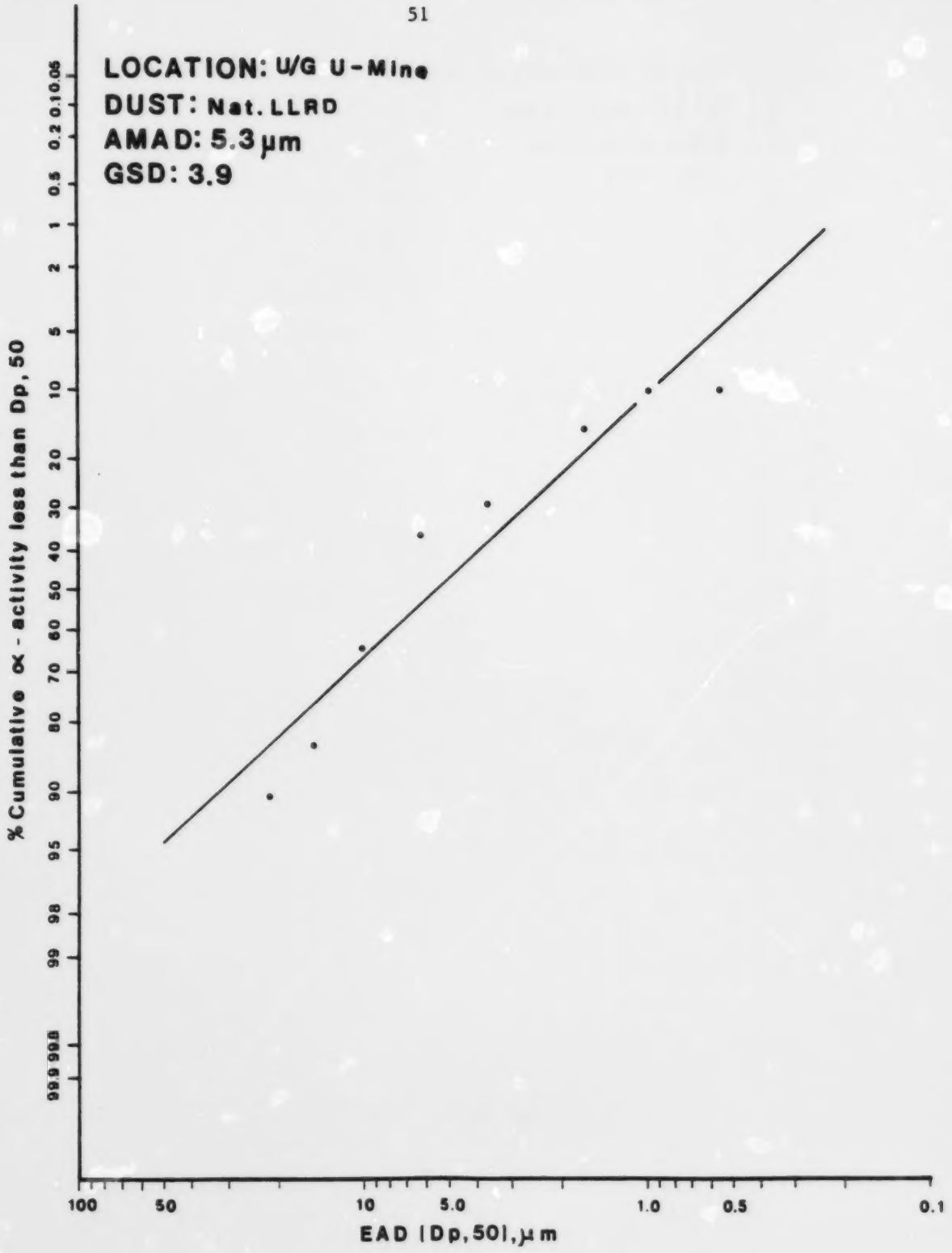


Fig. 18 - Percentage cumulative α-particle activity versus EAD (Dec. 7th and 10th) for the Marple 290.

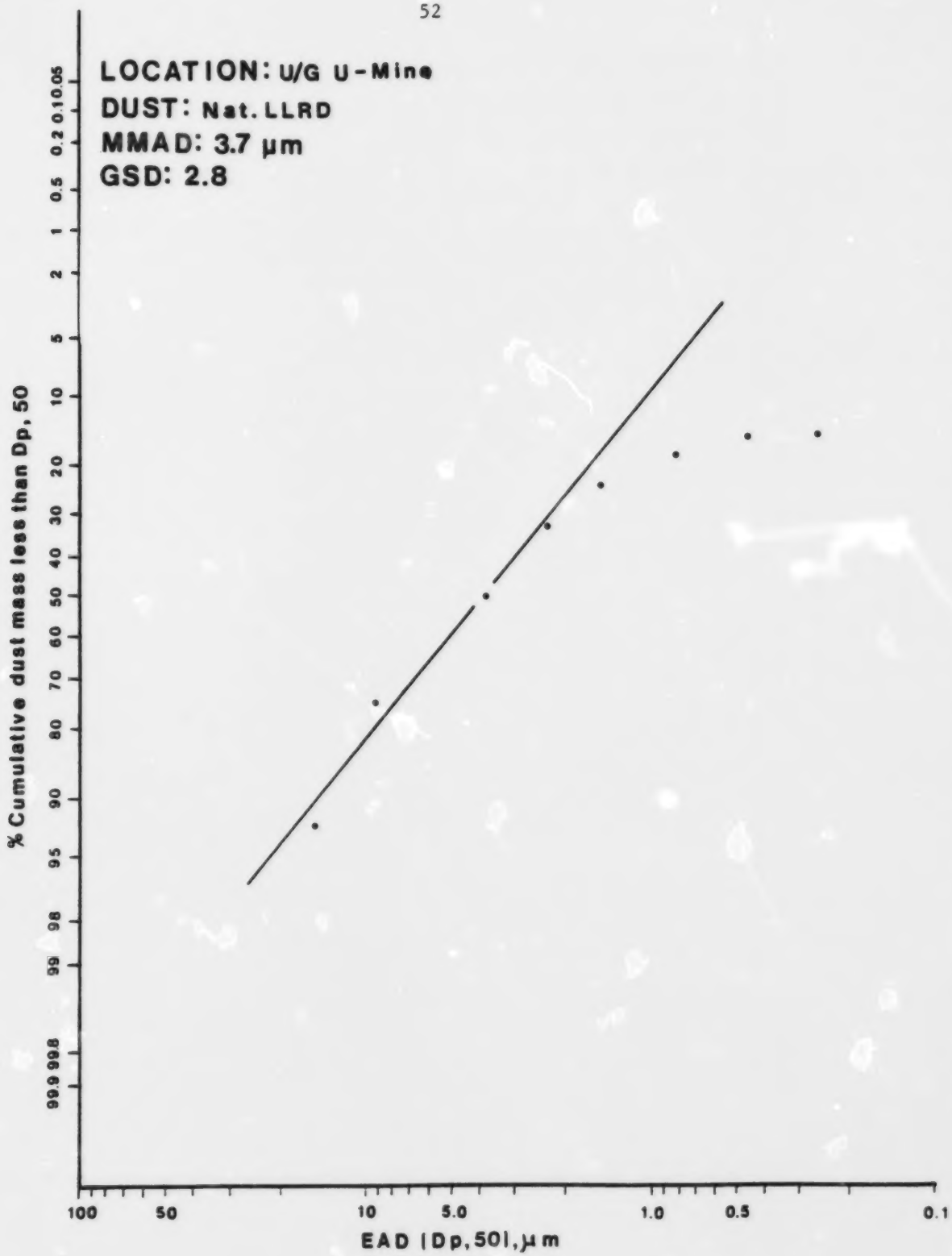

LOCATION: U/G U-Mine
DUST: Nat. LLRD
MMAD: 3.7 µm
GSD: 2.8
% Cumulative dust mass less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 19 - Percentage cumulative dust mass versus EAD (Dec. 13th, 14th and 17th) for the Sierra 210.

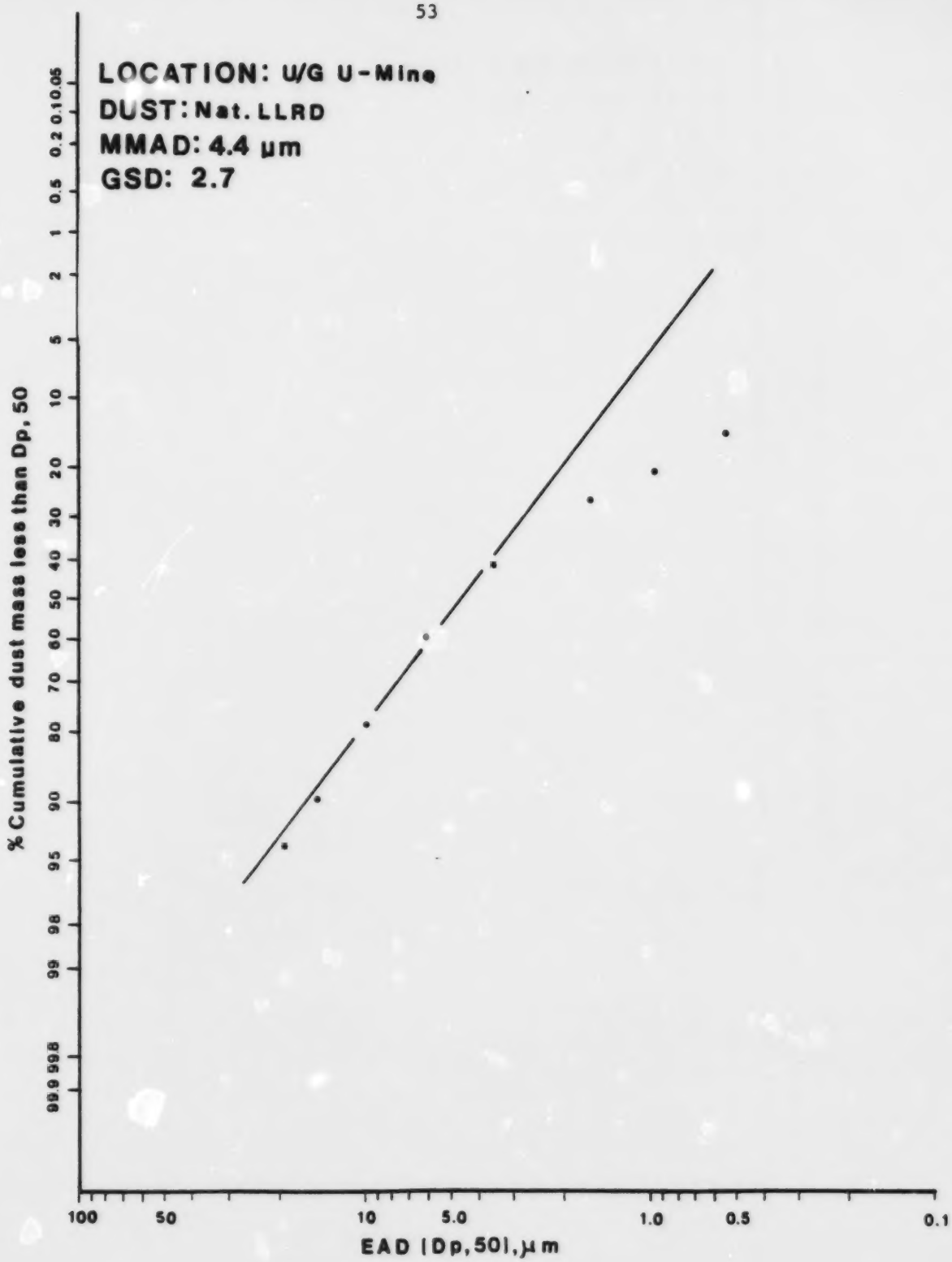

LOCATION: U/G U-Mine
DUST: Nat. LLRD
MMAD: 4.4 µm
GSD: 2.7
% Cumulative dust mass less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 20 - Percentage cumulative dust mass versus EAD (Dec. 13th, 14th and 17th) for the Marple 290.

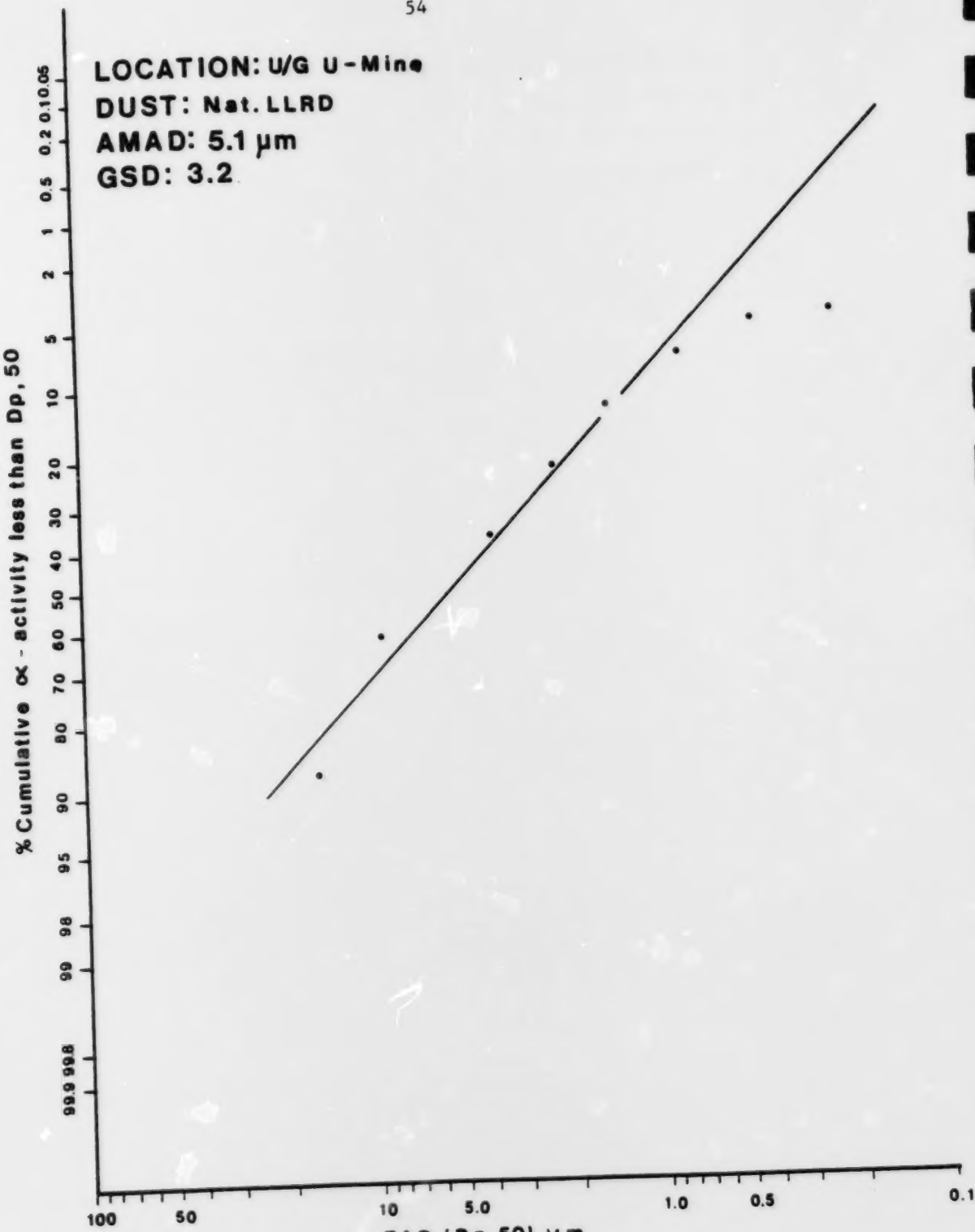


Fig. 21 - Percentage cumulative α-particle activity versus EAD. (Dec. 13th, 14th and 17th) for the Sierra 210.

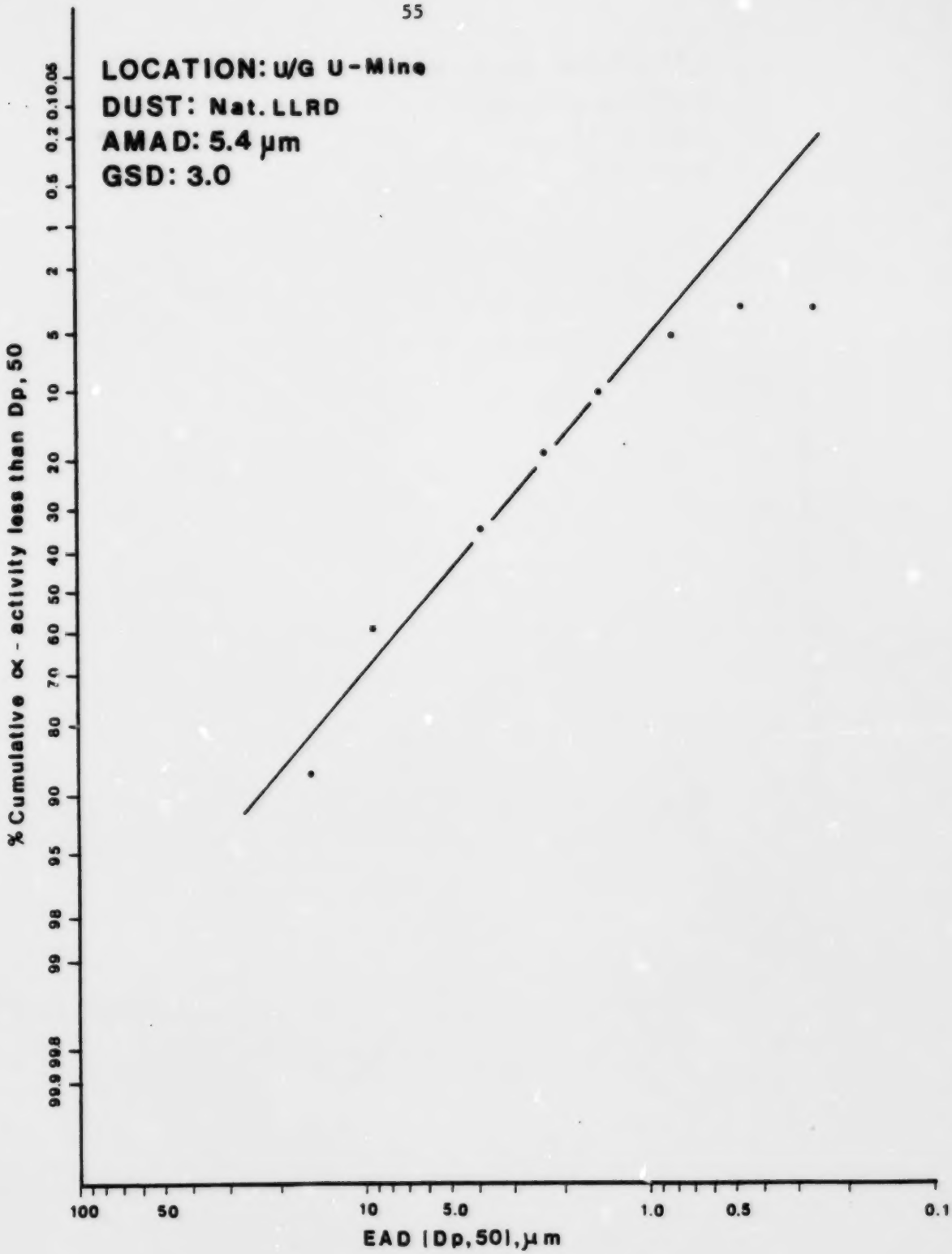

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 5.4 µm
GSD: 3.0
% Cumulative α - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), µm

Fig. 22 - Percentage cumulative α-particle activity versus EAD (Dec. 13th, 14th and 17th) for the Sierra 210 (corrected for substrate's background).

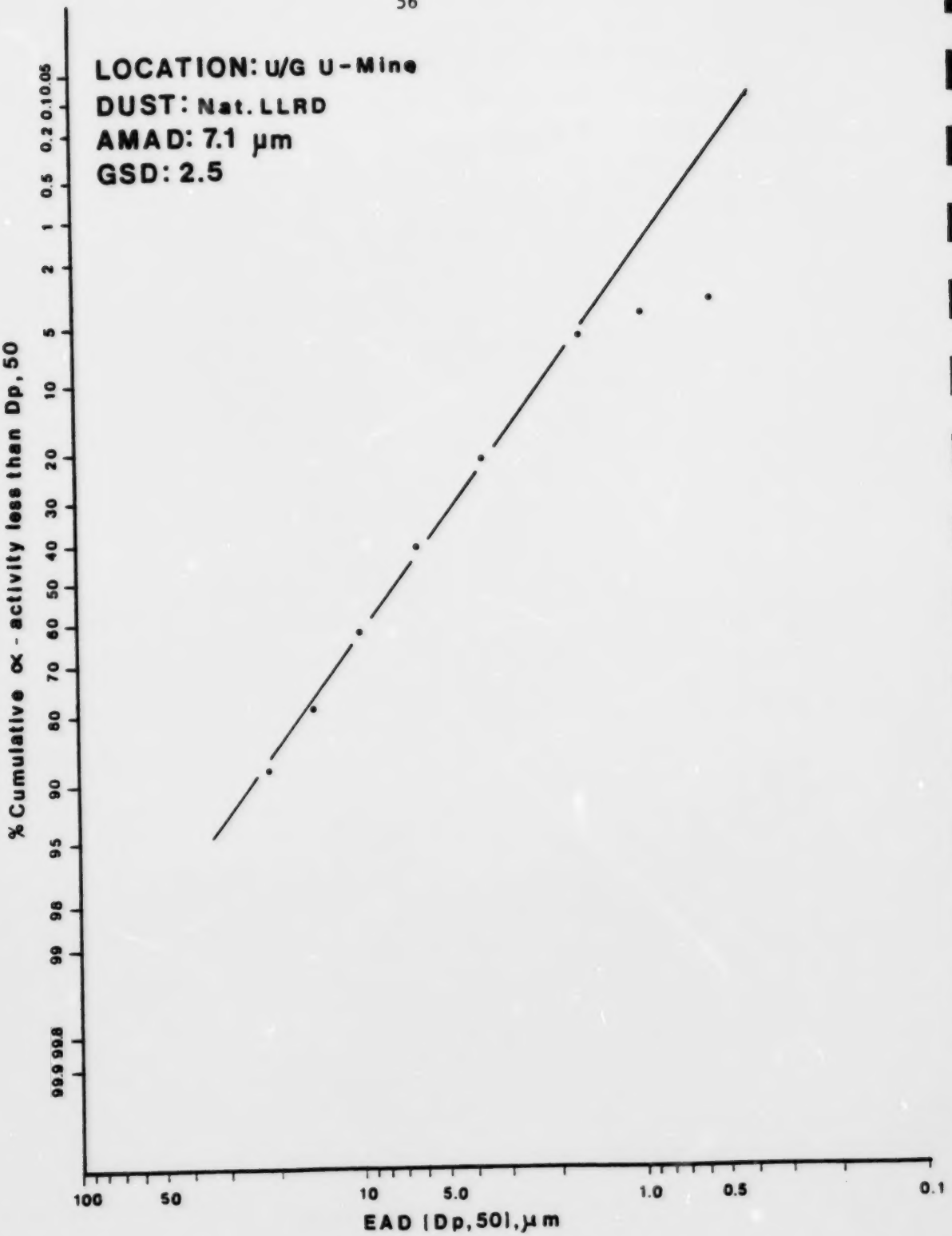

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 7.1 µm
GSD: 2.5
% Cumulative α - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), µm

Fig. 23 - Percentage cumulative α-particle activity versus EAD (Dec. 13th, 14th and 17th) for the Marple 290.

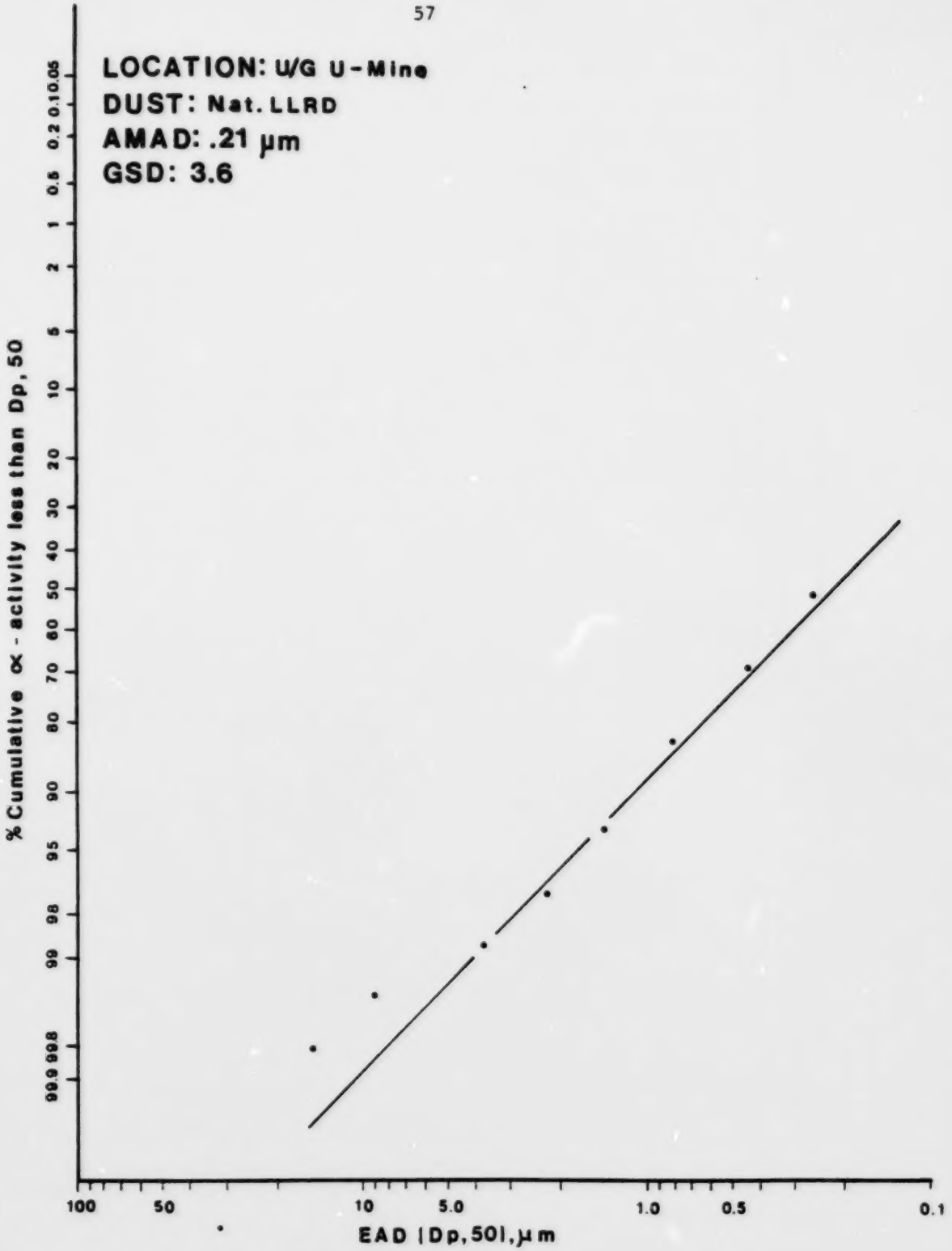

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: .21 µm
GSD: 3.6
% Cumulative ∝ - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), µm

Fig. 24 - Percentage cumulative α-particle activity versus EAD (^{220}Rn progeny) for the Sierra 210 (Dec. 13th, 14th and 17th).

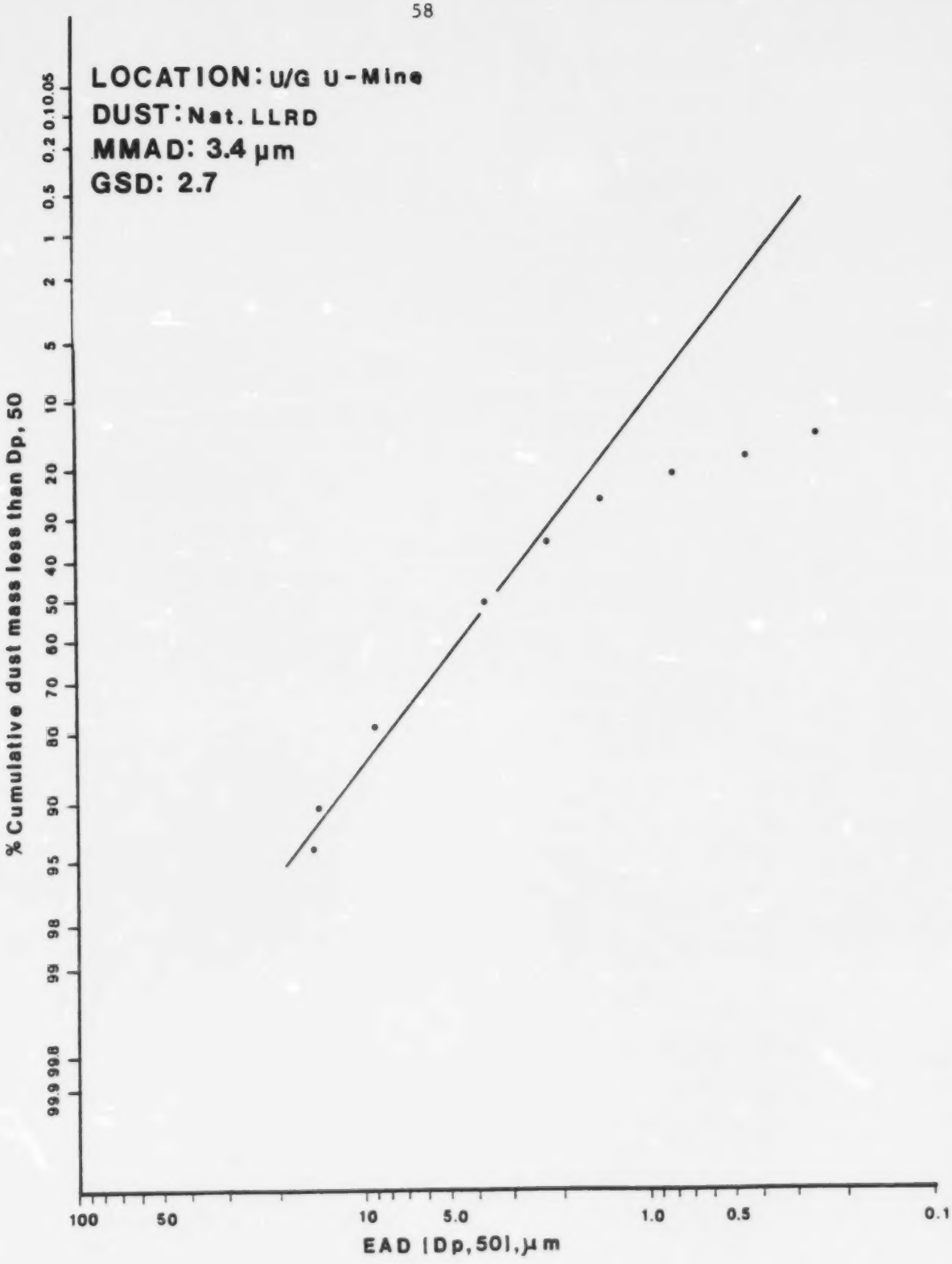


Fig. 25 - Percentage cumulative dust mass versus EAD (Dec. 18th, 19th and 20th) for the Sierra 210.

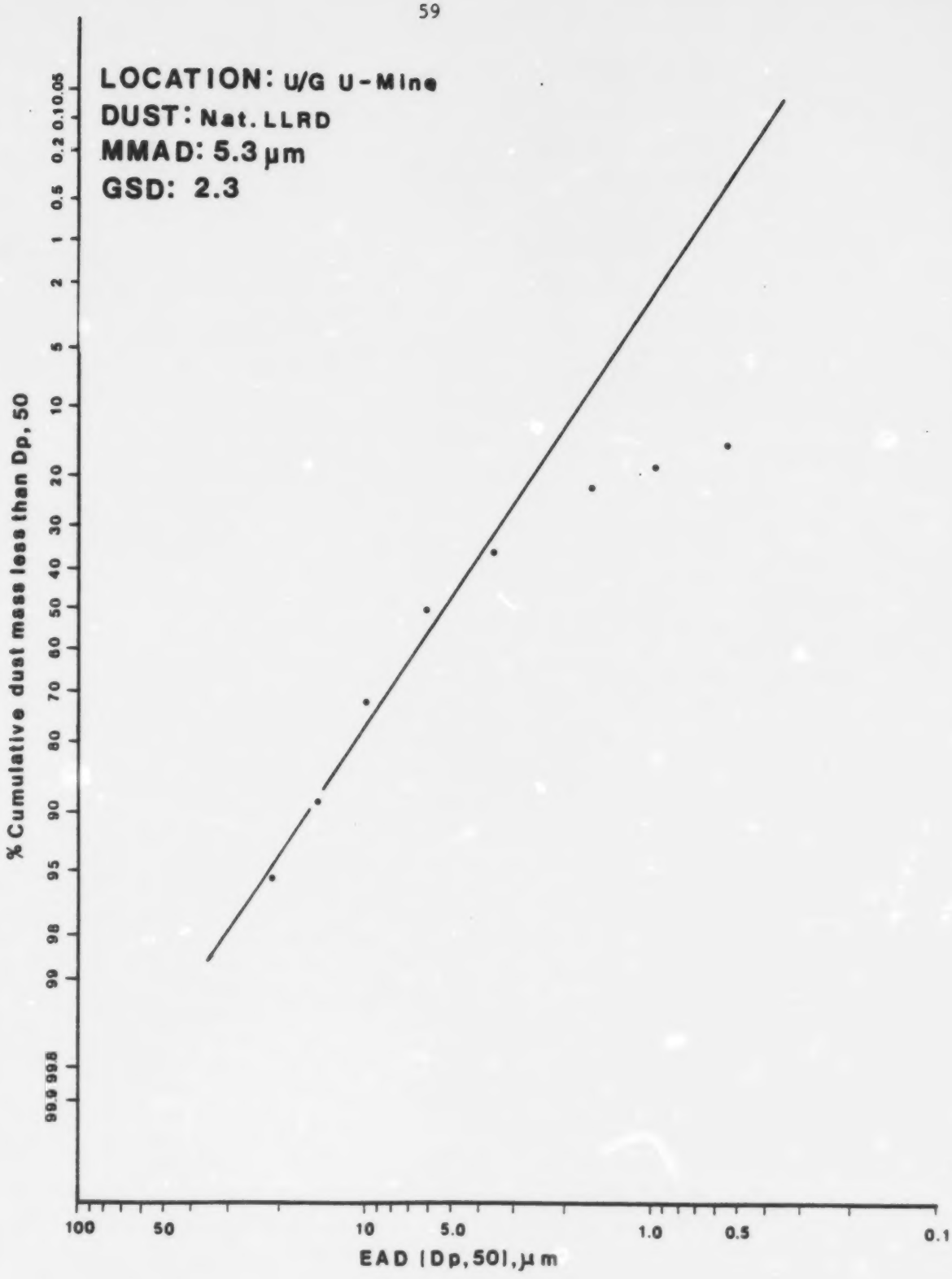

LOCATION: U/G U-Mine
DUST: Nat. LLRD
MMAD: 5.3 µm
GSD: 2.3
% Cumulative dust mass less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 26 - Percentage cumulative dust mass versus EAD (Dec. 18th, 19th and 20th) for the Marple 290.

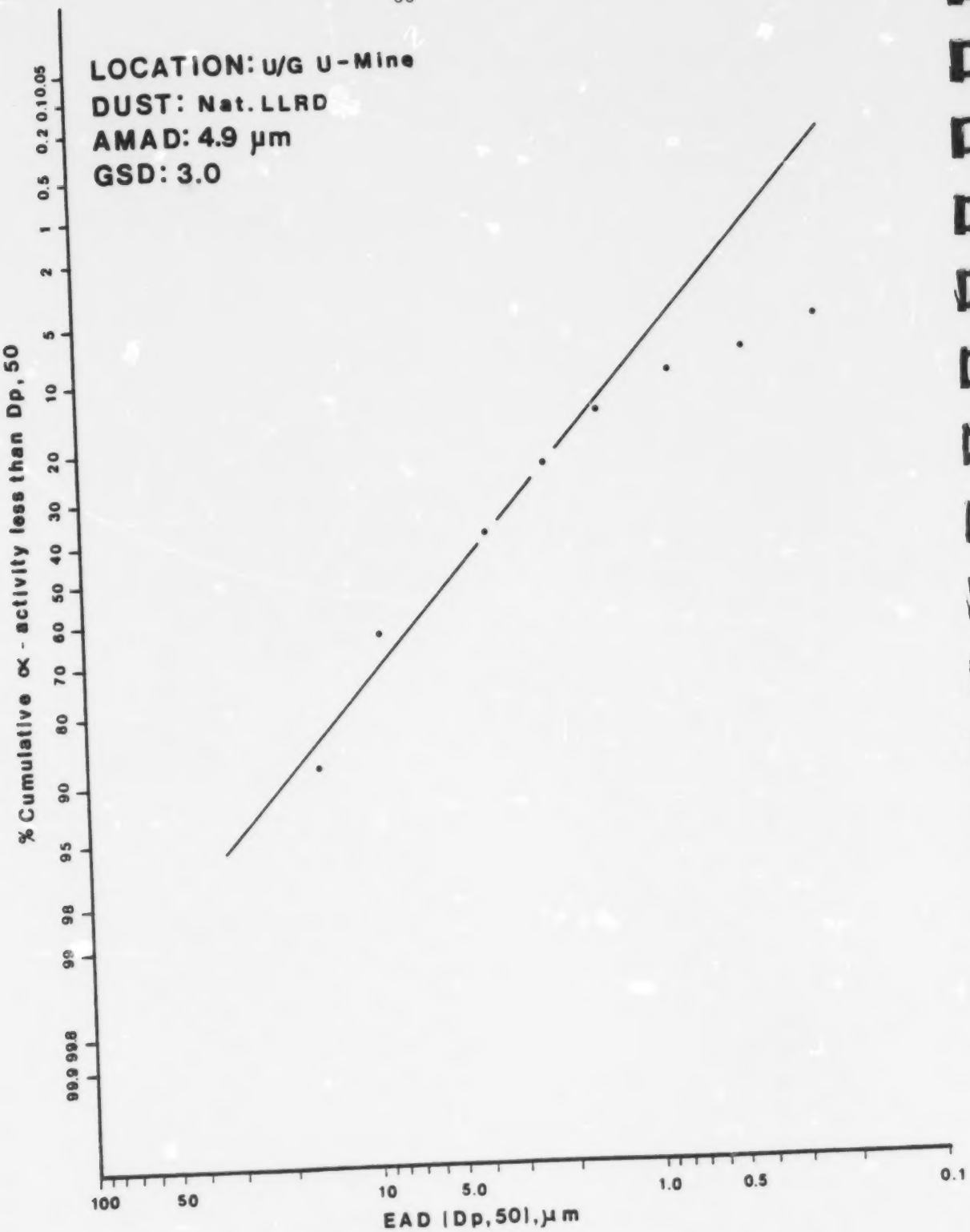

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 4.9 µm
GSD: 3.0
% Cumulative ∝ - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp, 50), µm

Fig. 27 - Percentage cumulative α-particle activity versus EAD (Dec. 18th, 19th and 20th) for the Sierra 210.

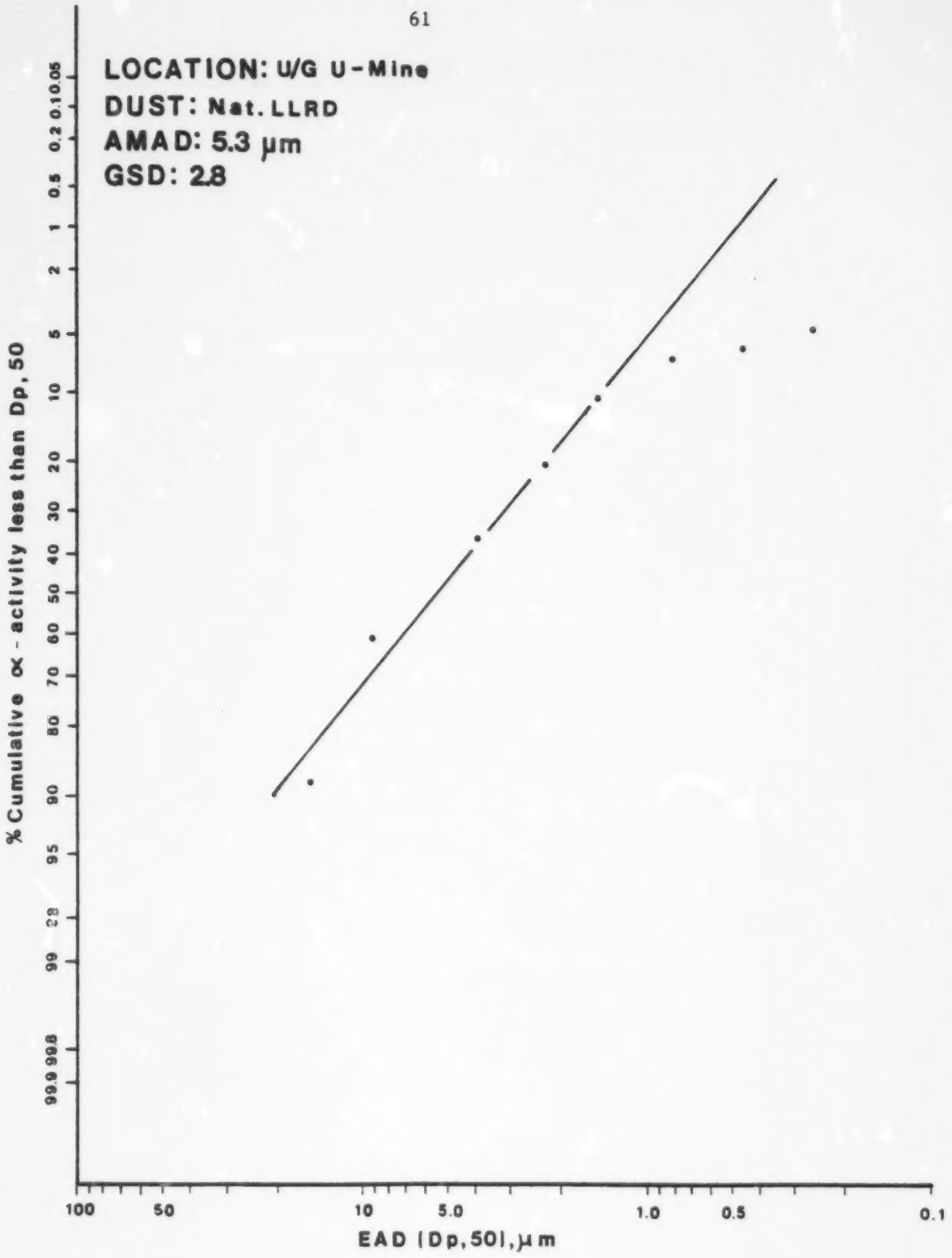

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 5.3 µm
GSD: 2.8
% Cumulative α - activity less than Dp,50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 28 - Percentage cumulative α-particle activity versus EAD (Dec. 18th, 19th and 20th) for the Sierra 210 (corrected for substrate's background).

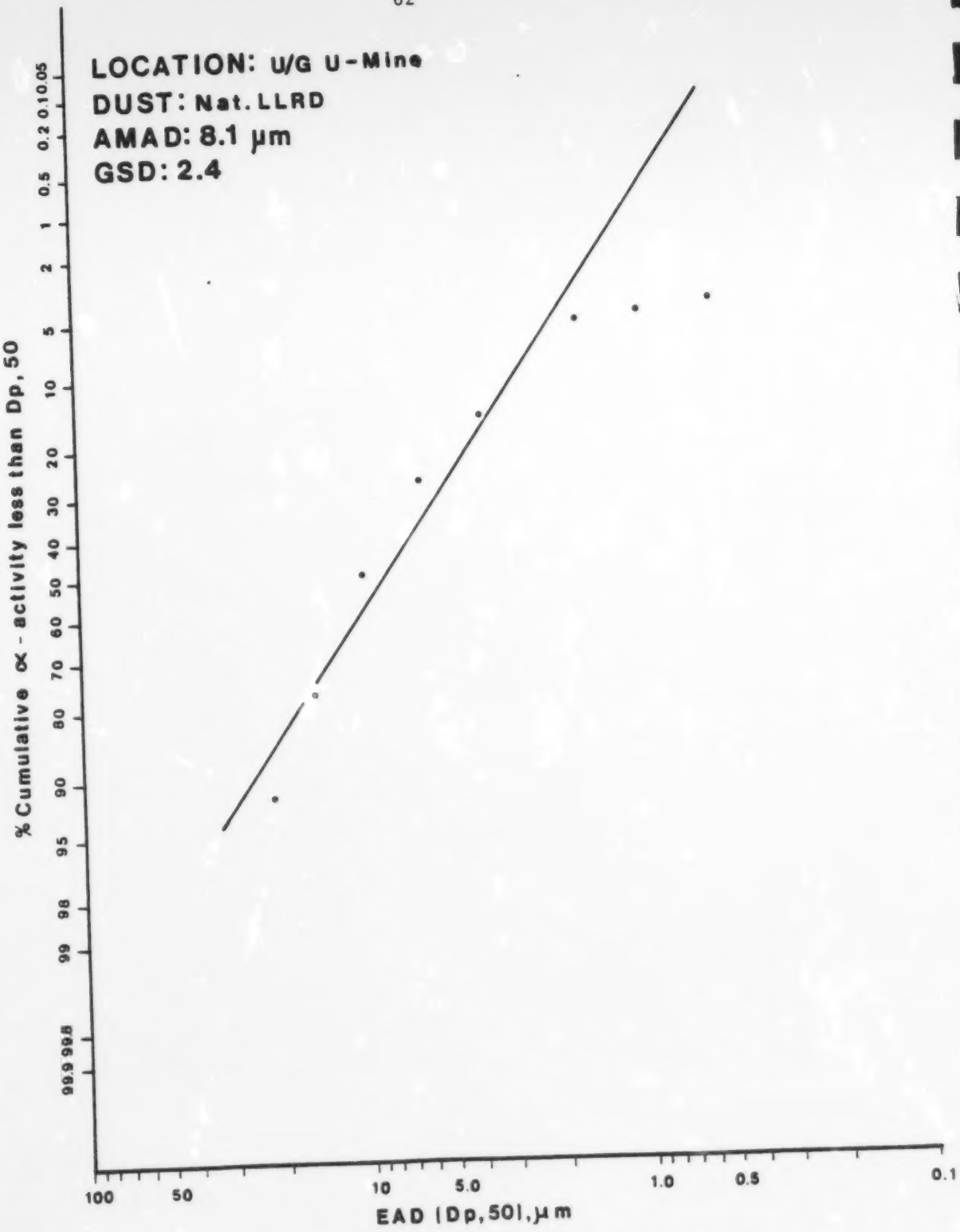

LOCATION: U/G U-Mine
DUST: Nat. LLRD
AMAD: 8.1 µm
GSD: 2.4
% Cumulative α - activity less than Dp, 50
0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9
100 50 10 5.0 1.0 0.5 0.1
EAD (Dp,50), µm

Fig. 29 - Percentage cumulative α-particle activity versus EAD (Dec. 18th, 19th and 20th) for the Marple 290.

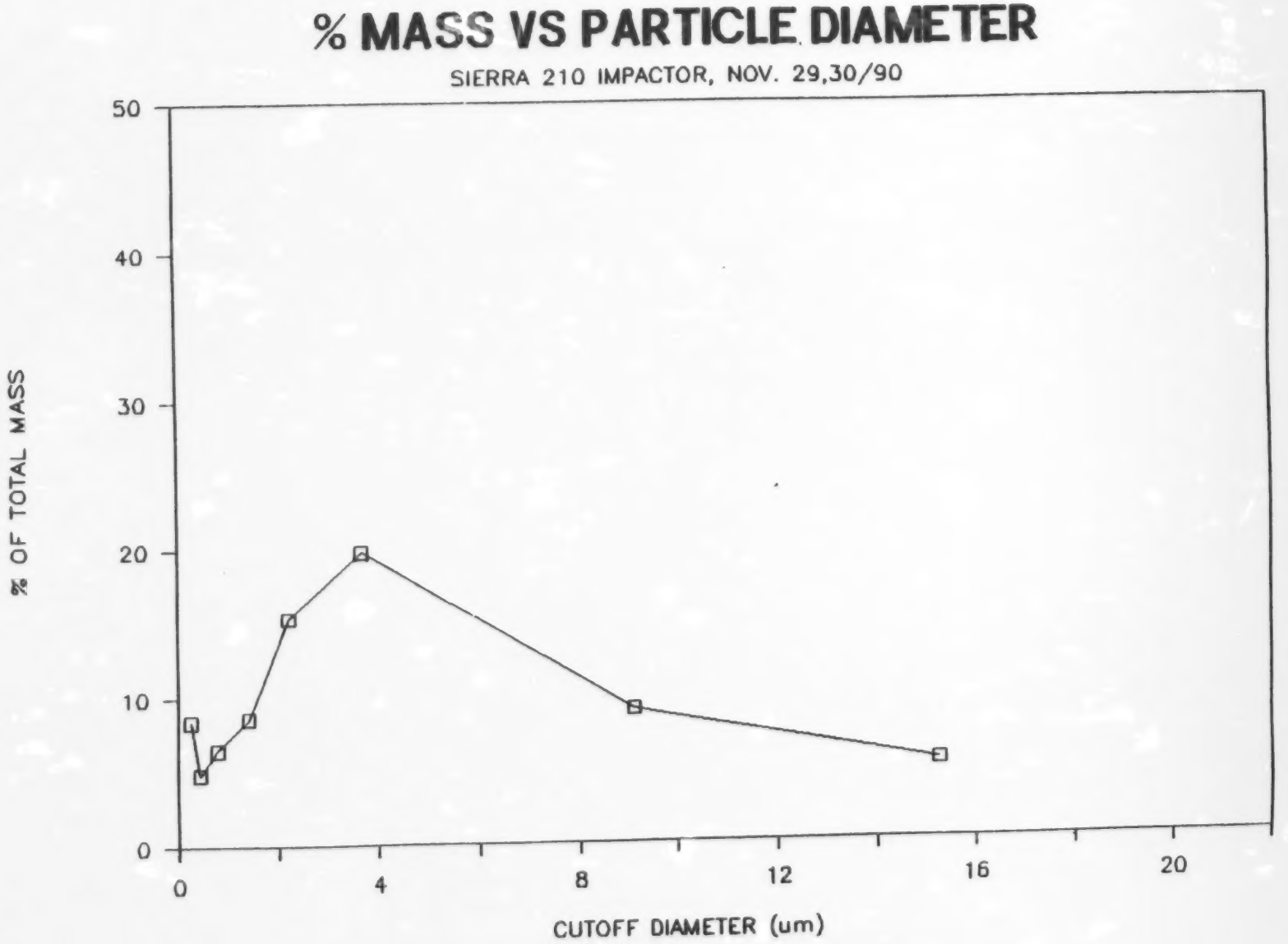


Fig. 30 - Percentage of total dust mass versus particle cut-off diameter.

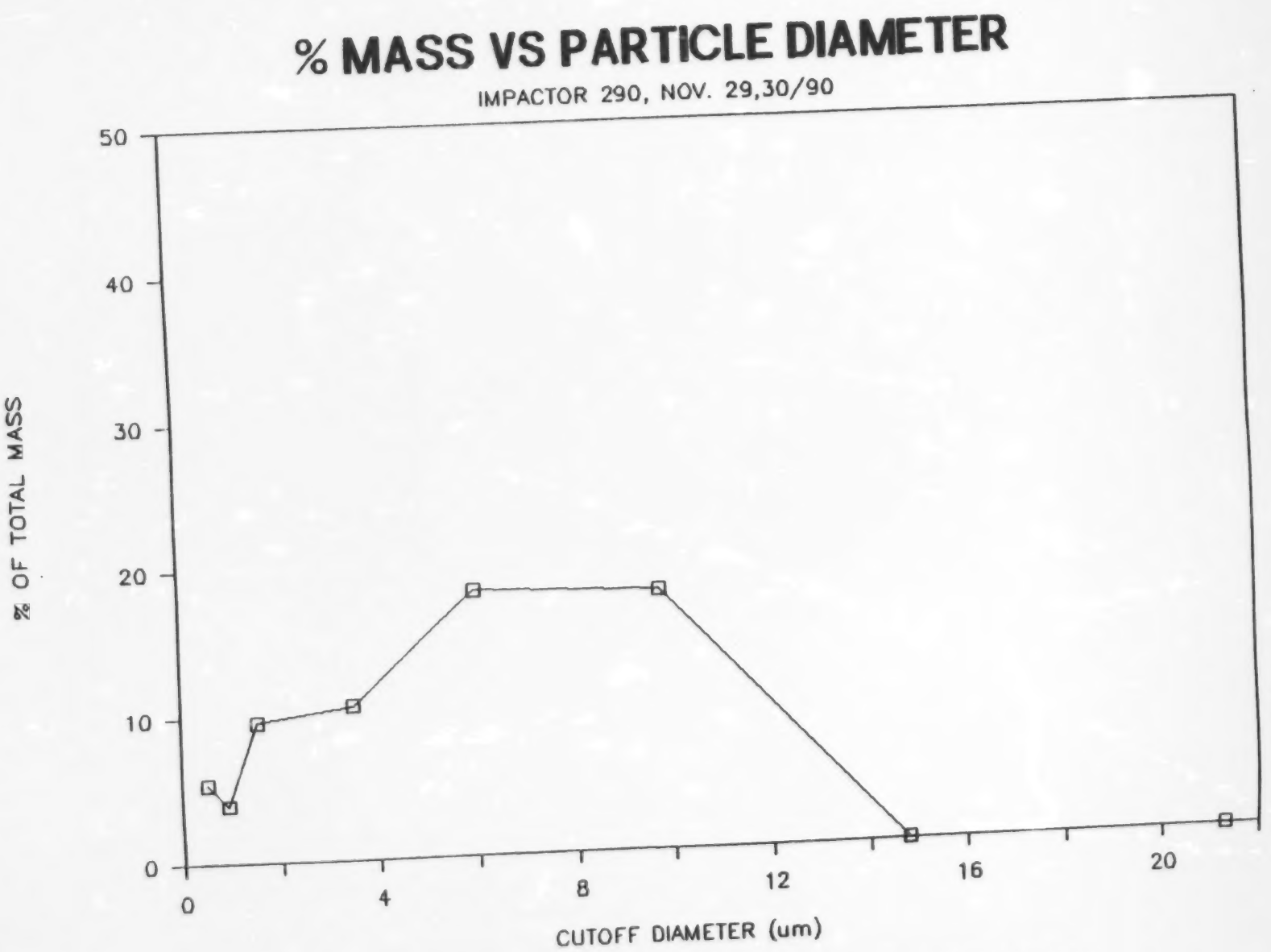


Fig. 31 - Percentage of total dust mass versus particle cut-off diameter.

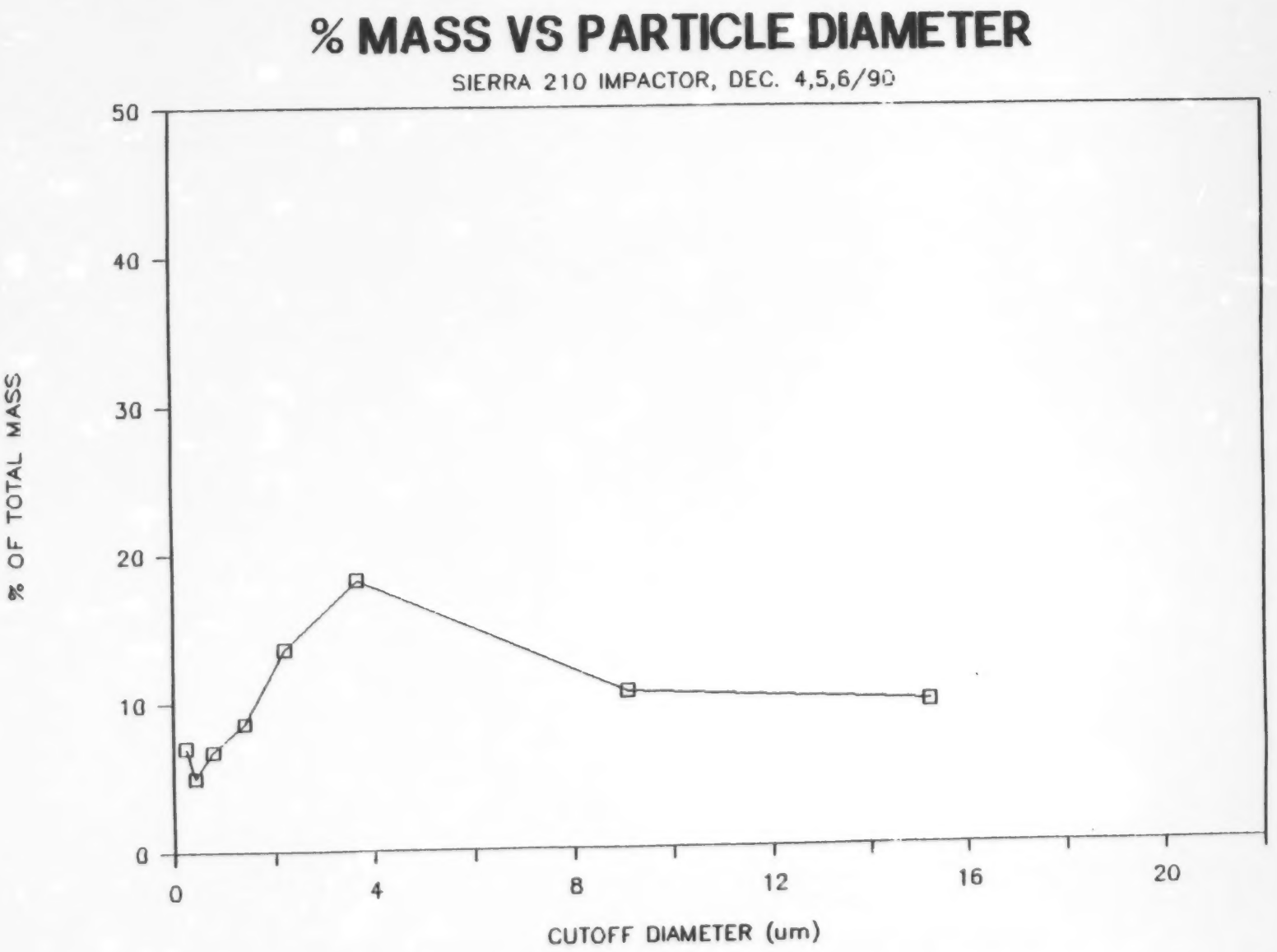


Fig. 32 - Percentage of total dust mass versus particle cut-off diameter.

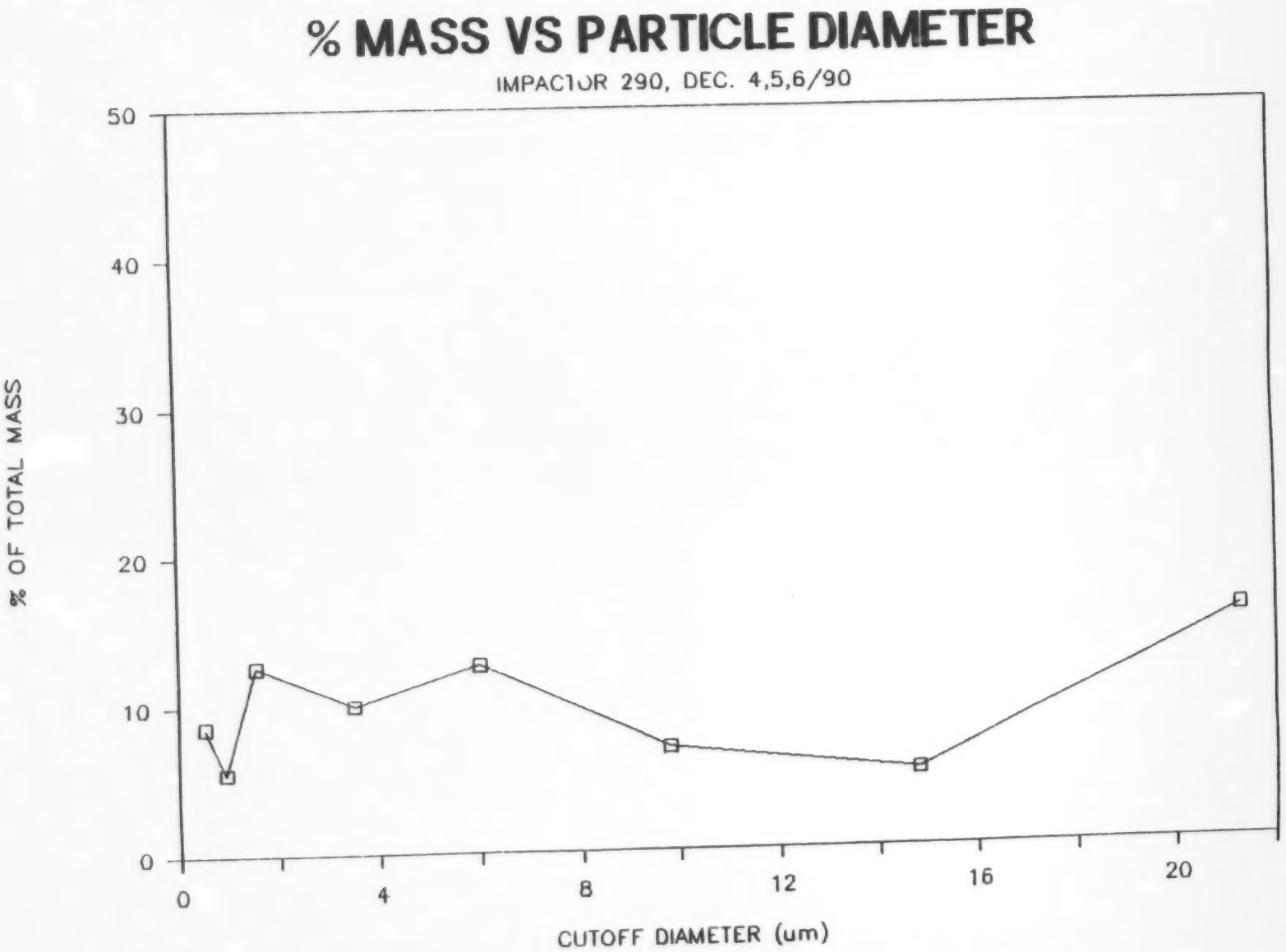


Fig. 33 - Percentage of total dust mass versus particle cut-off diameter.

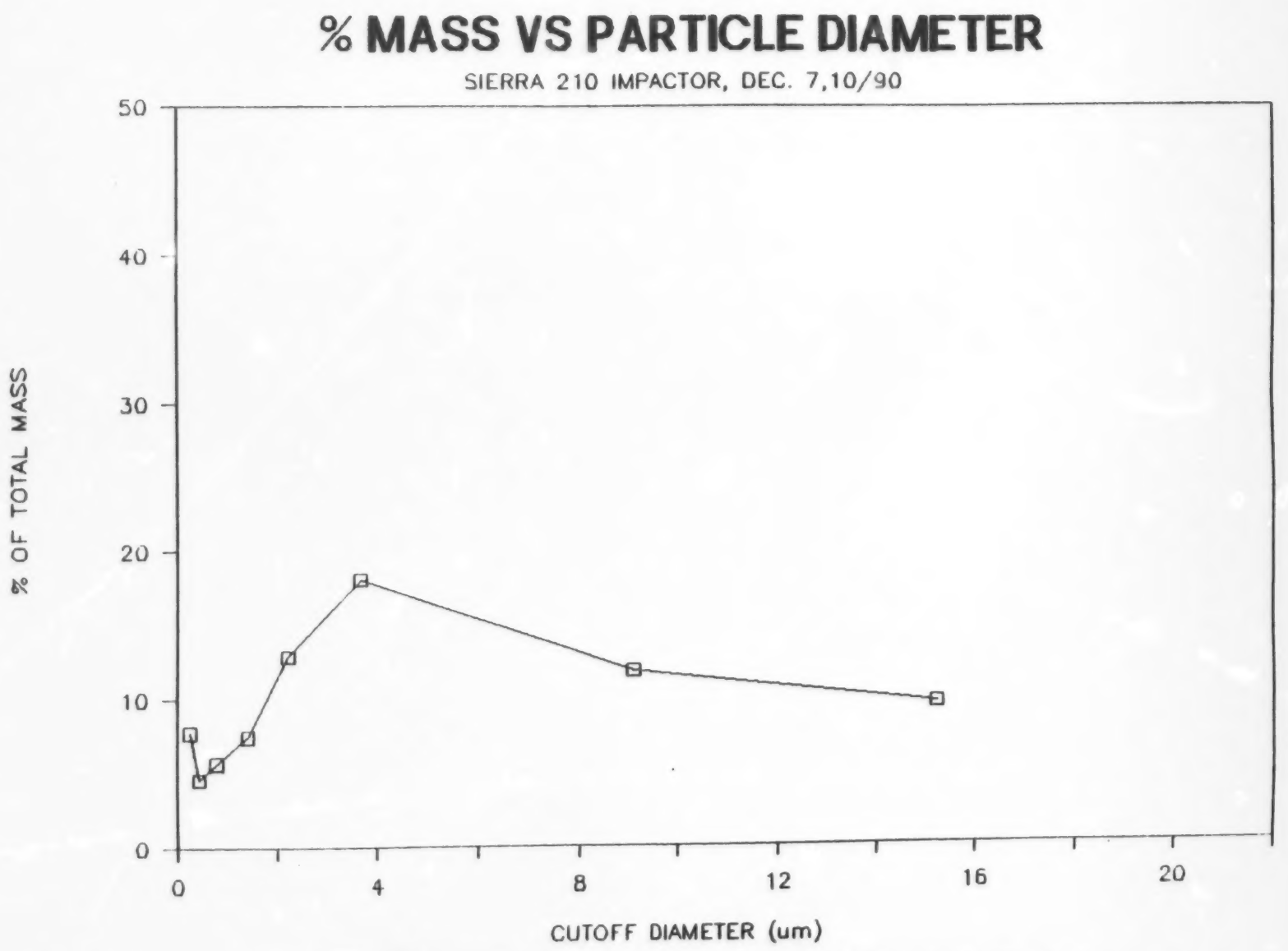


Fig. 34 - Percentage of total dust mass versus particle cut-off diameter.

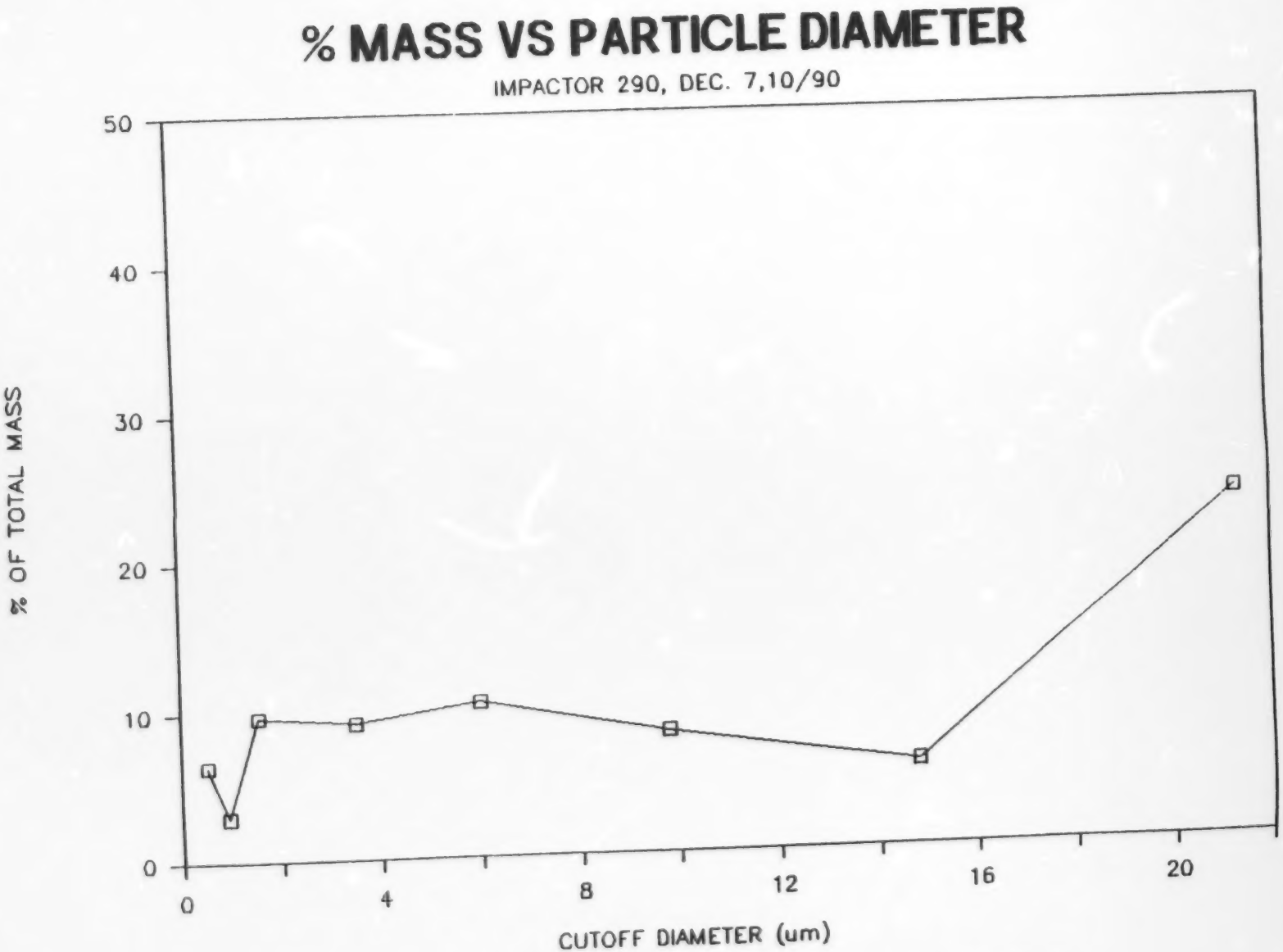


Fig. 35 - Percentage of total dust mass versus particle cut-off diameter.

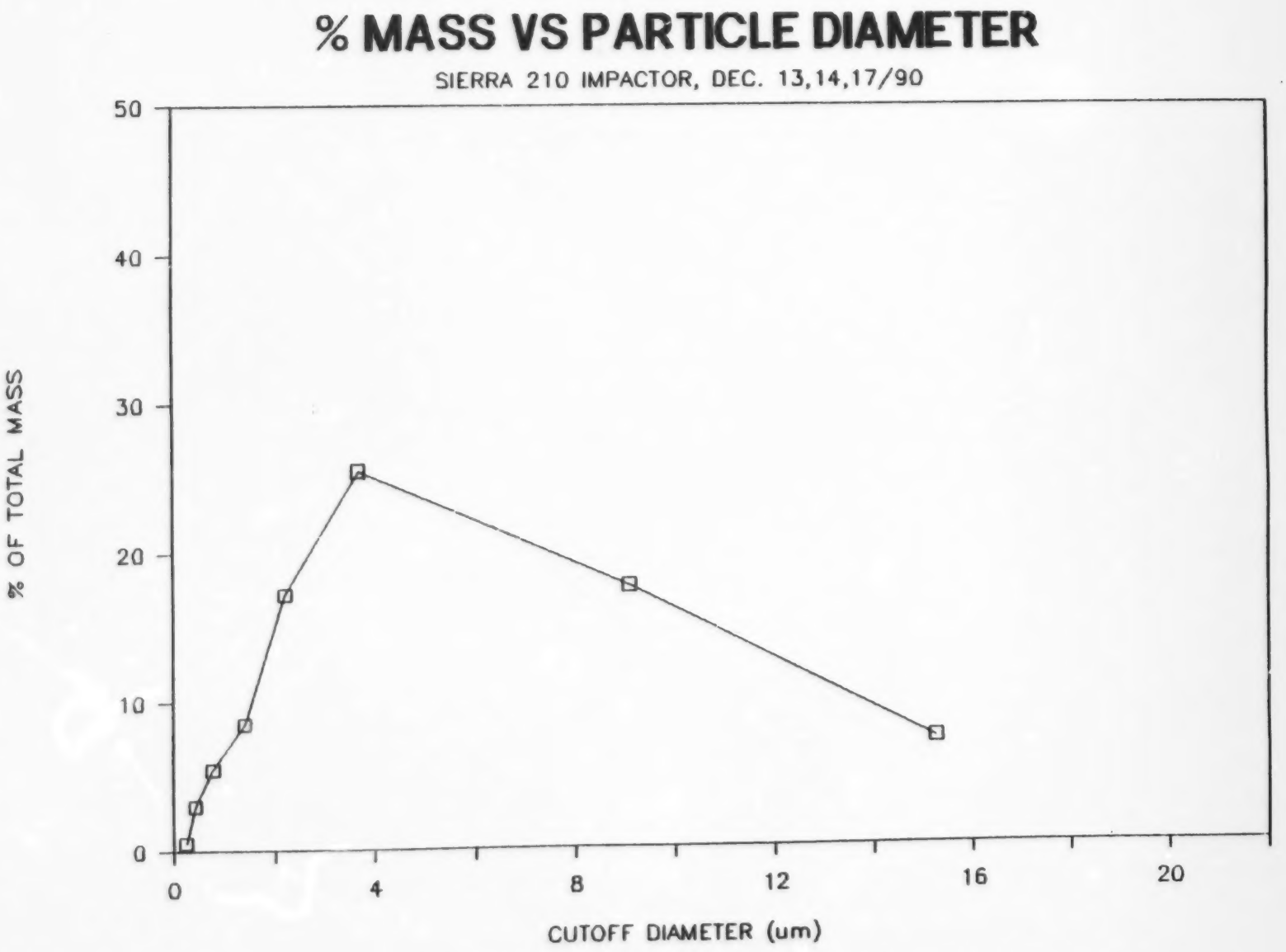


Fig. 36 - Percentage of total dust mass versus particle cut-off diameter

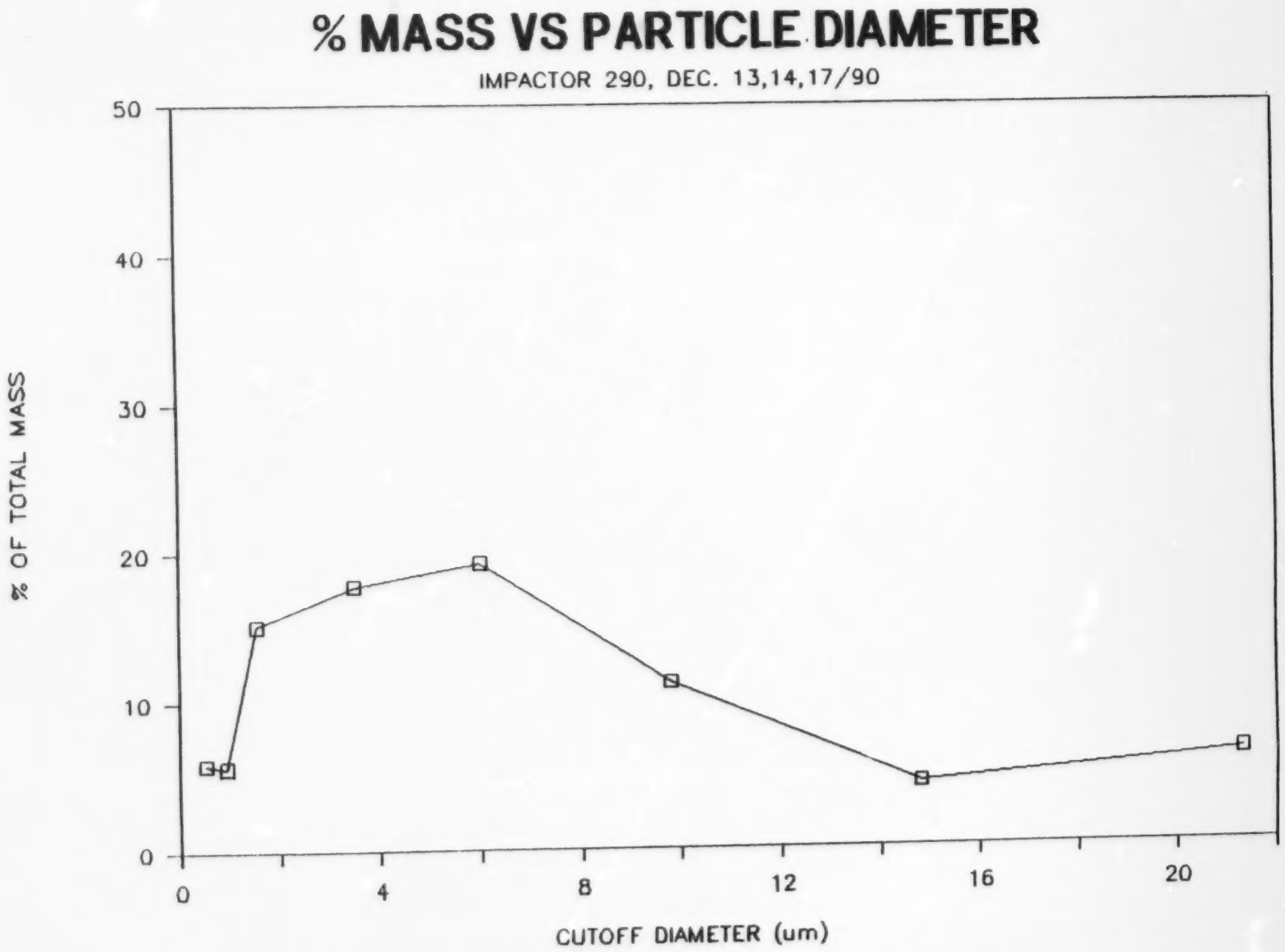


Fig. 37 - Percentage of total dust mass versus particle cut-off diameter.

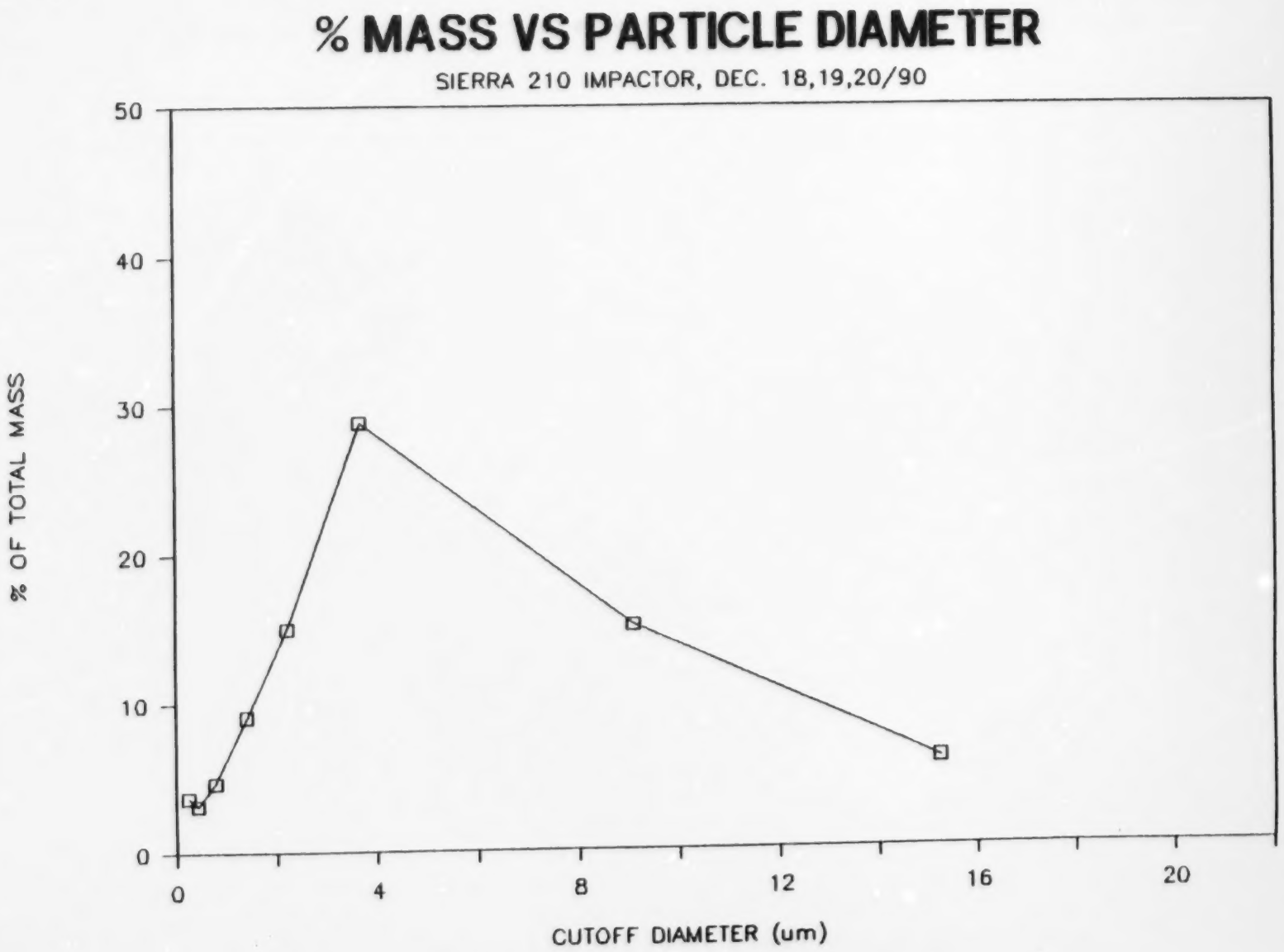


Fig. 38 - Percentage of total dust mass versus particle cut-off diameter.

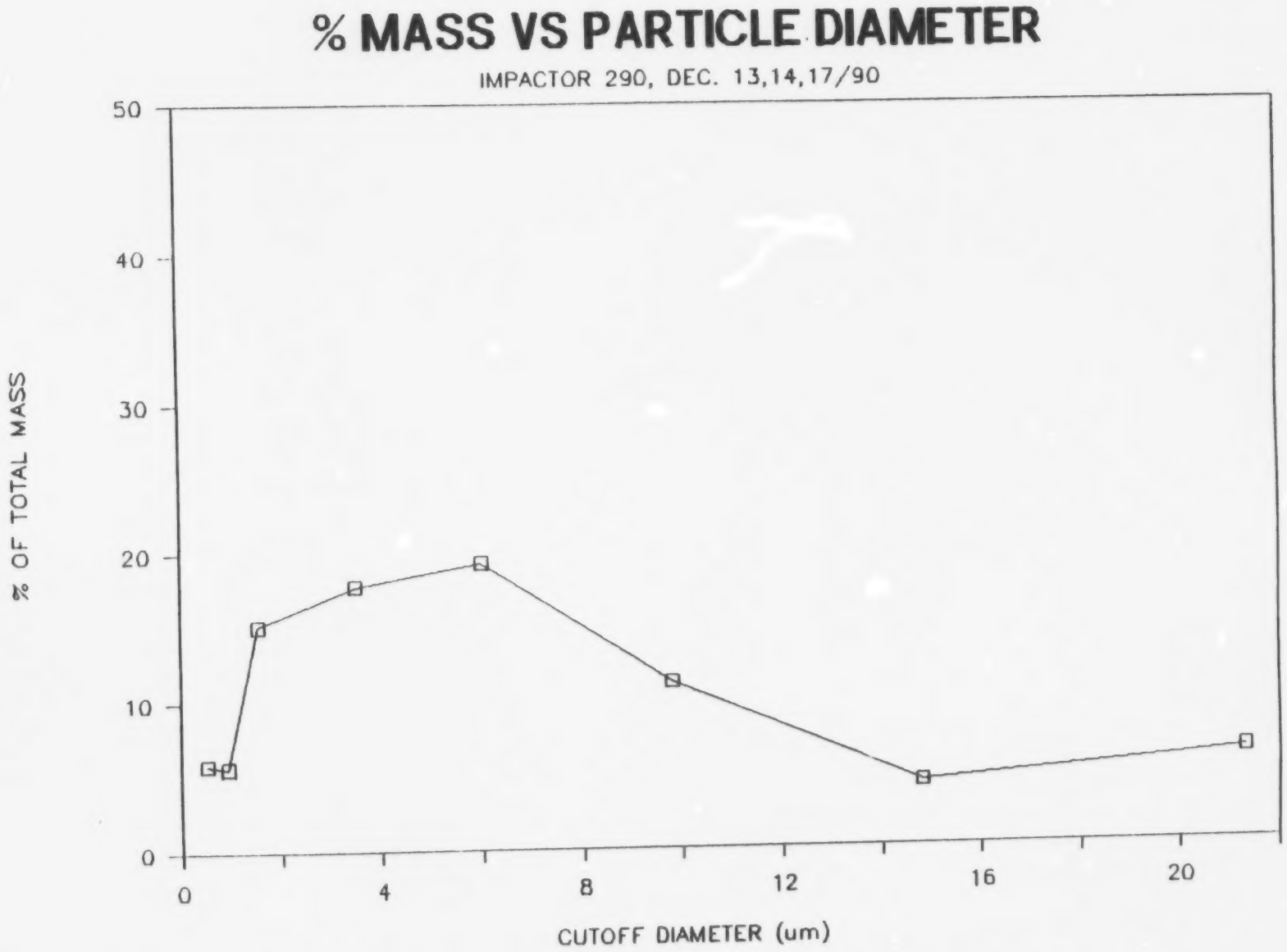


Fig. 37 - Percentage of total dust mass versus particle cut-off diameter.

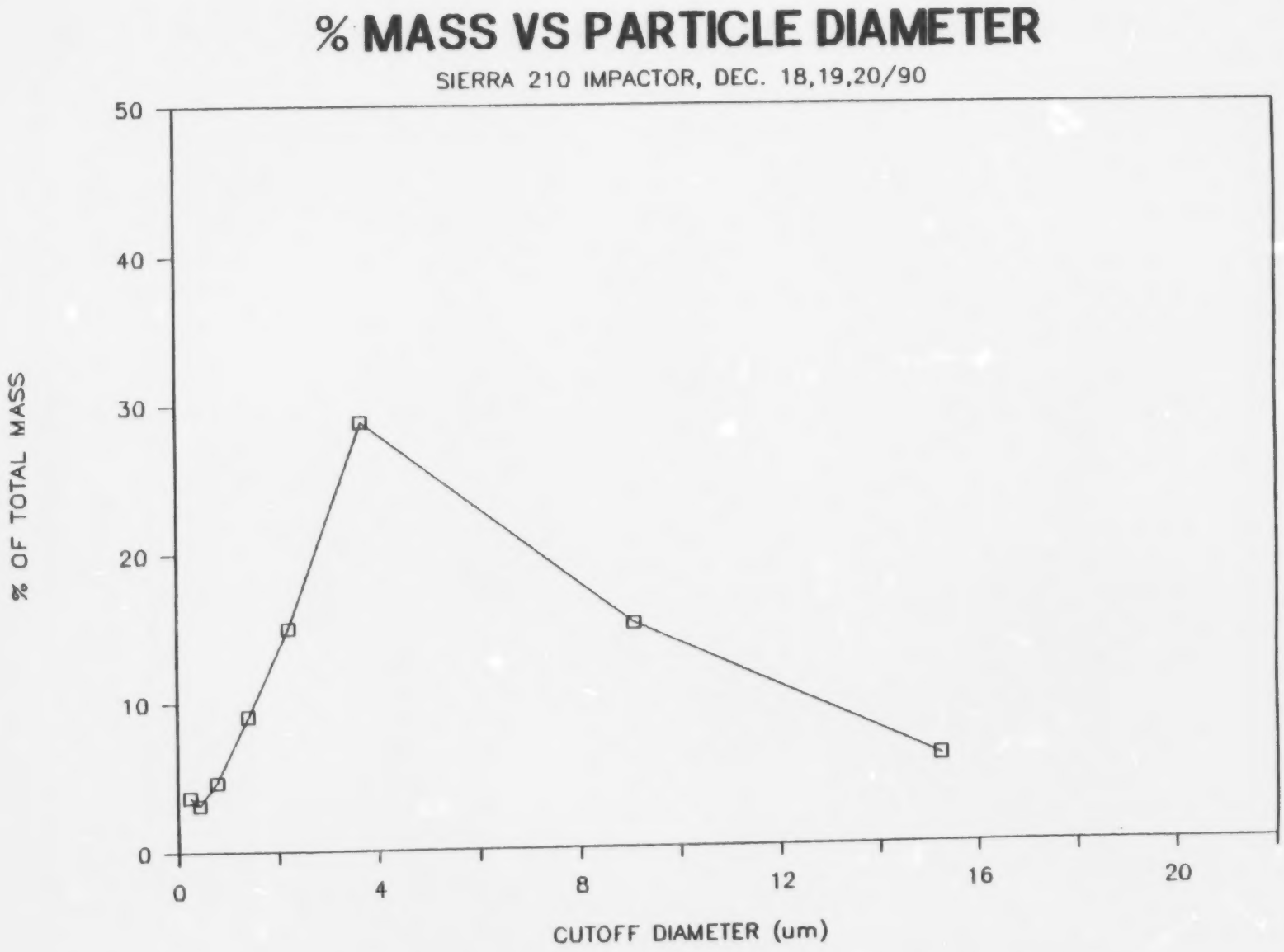


Fig. 38 - Percentage of total dust mass versus particle cut-off diameter.

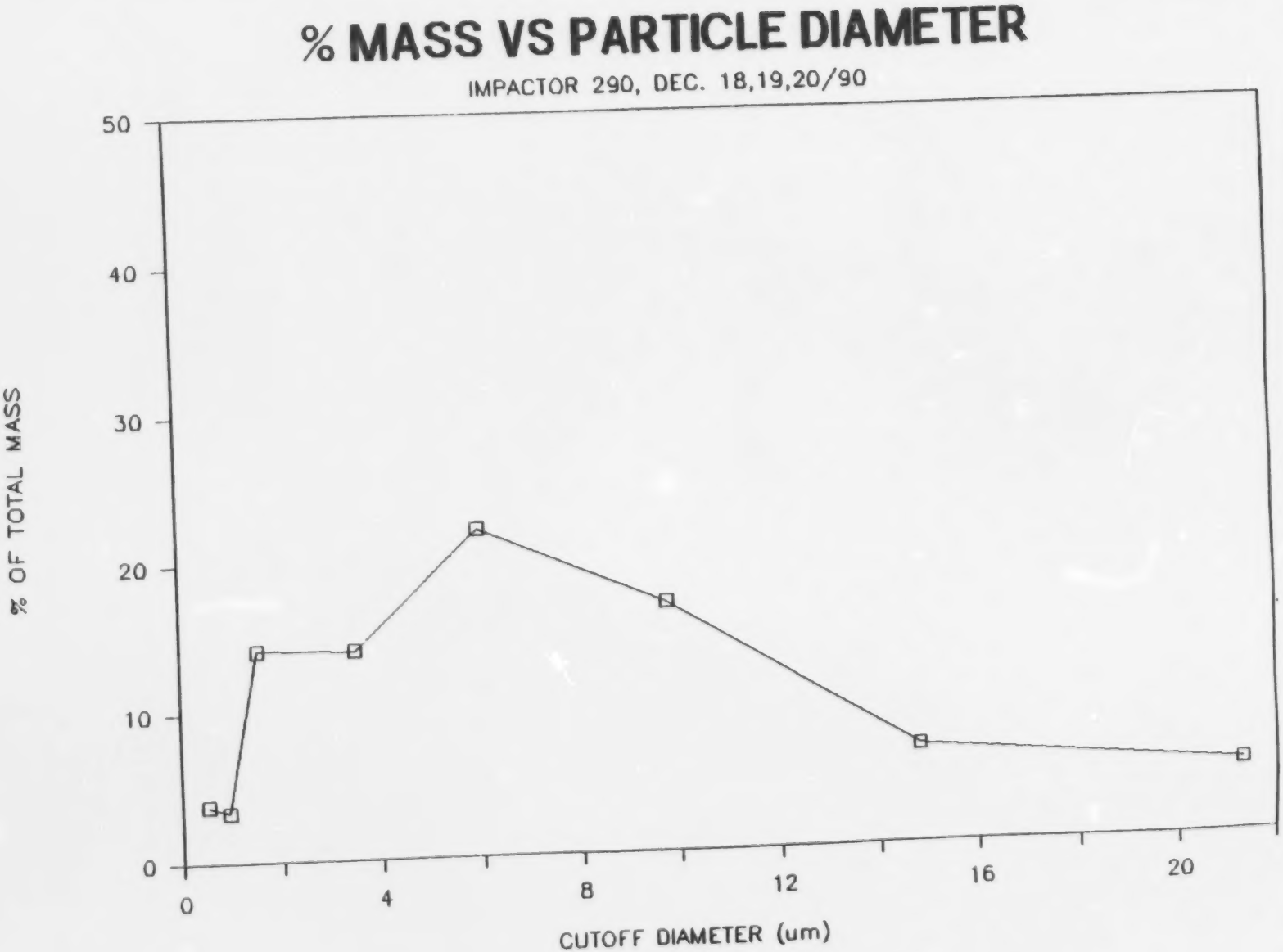


Fig. 39 - Percentage of total dust mass versus particle cut-off diameter.

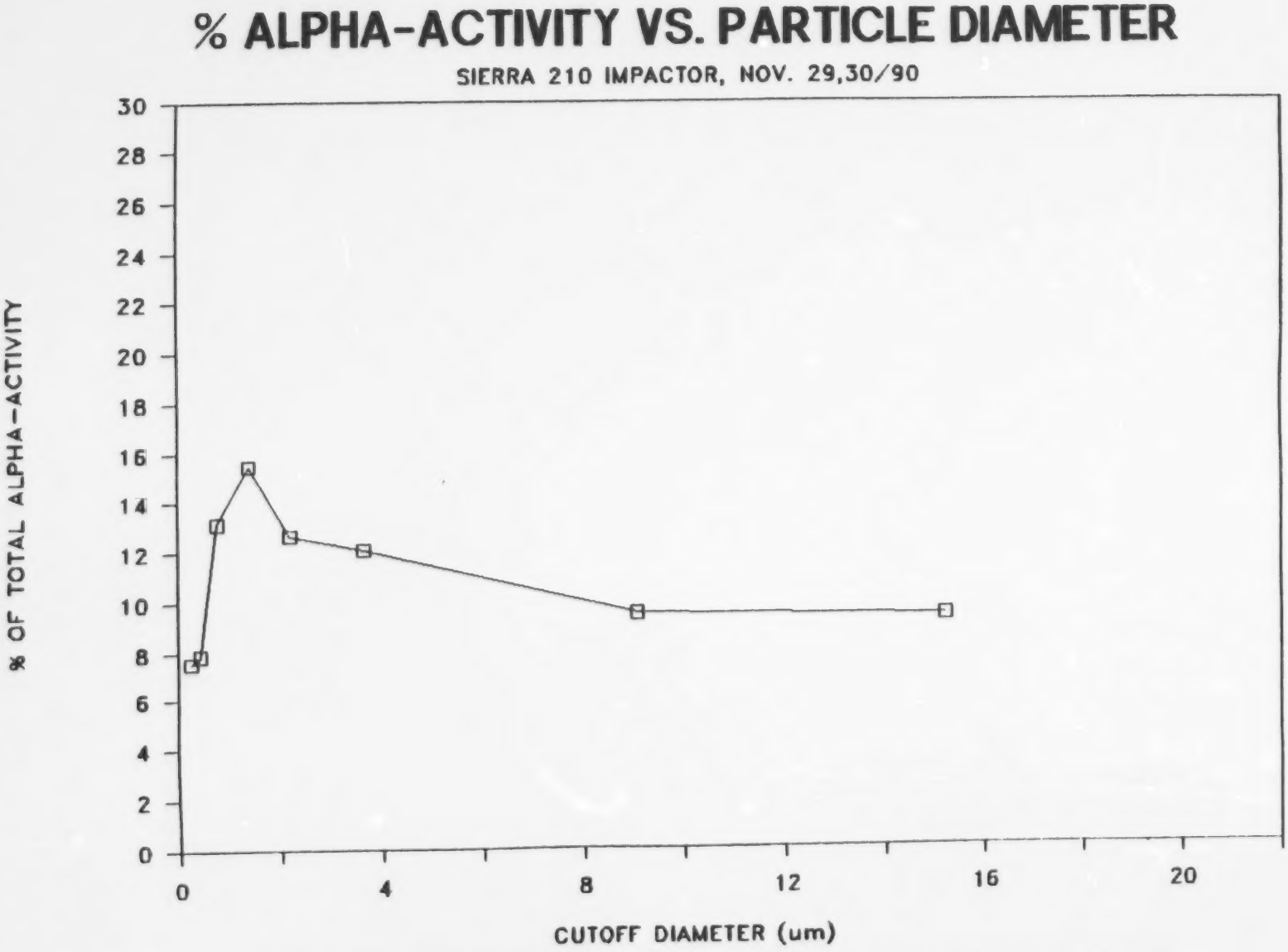


Fig. 40 - Percentage of total α-particle activity versus particle cut-off diameter.

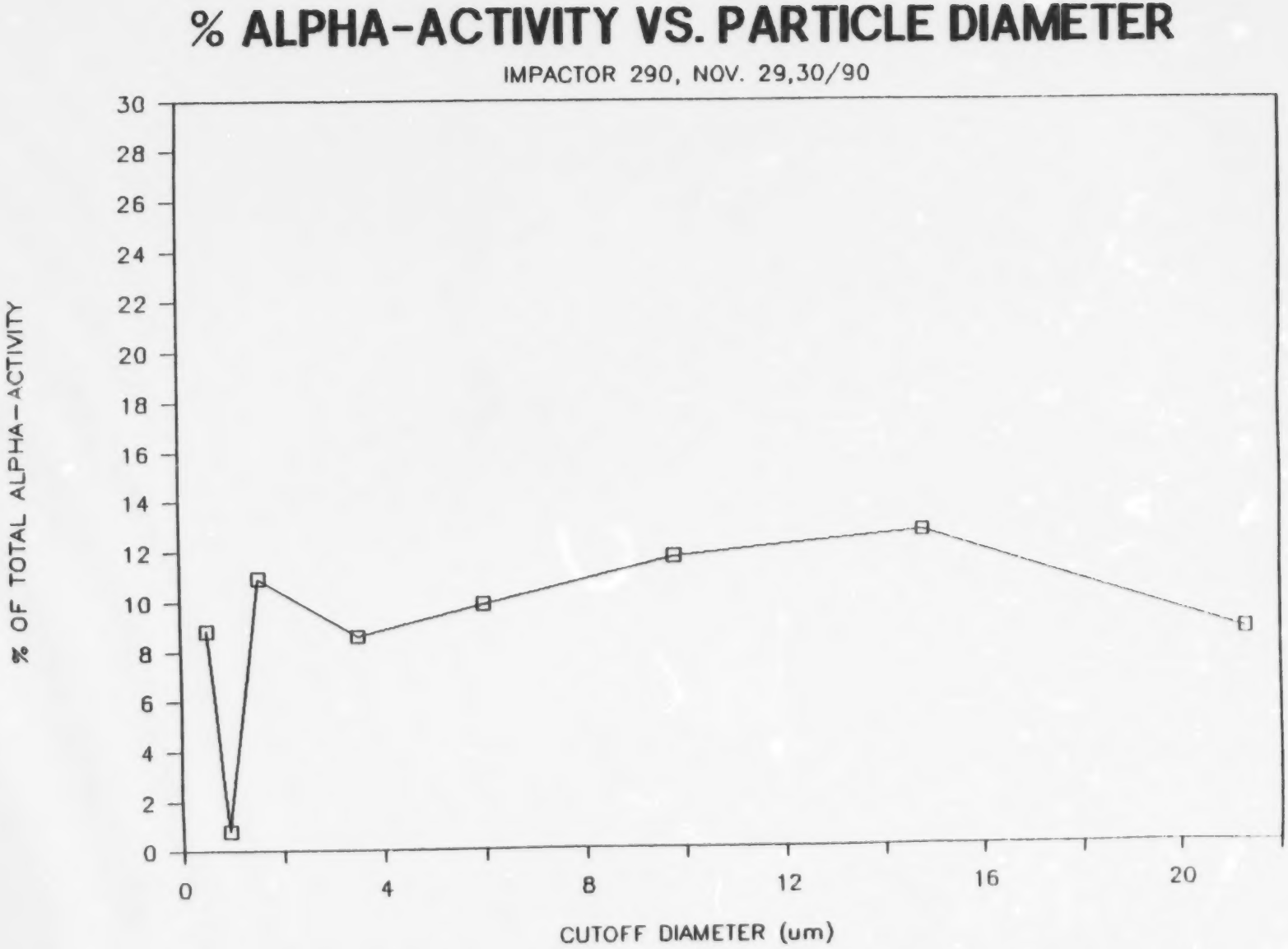


Fig. 41 - Percentage of total α-particle activity versus particle cut-off diameter.

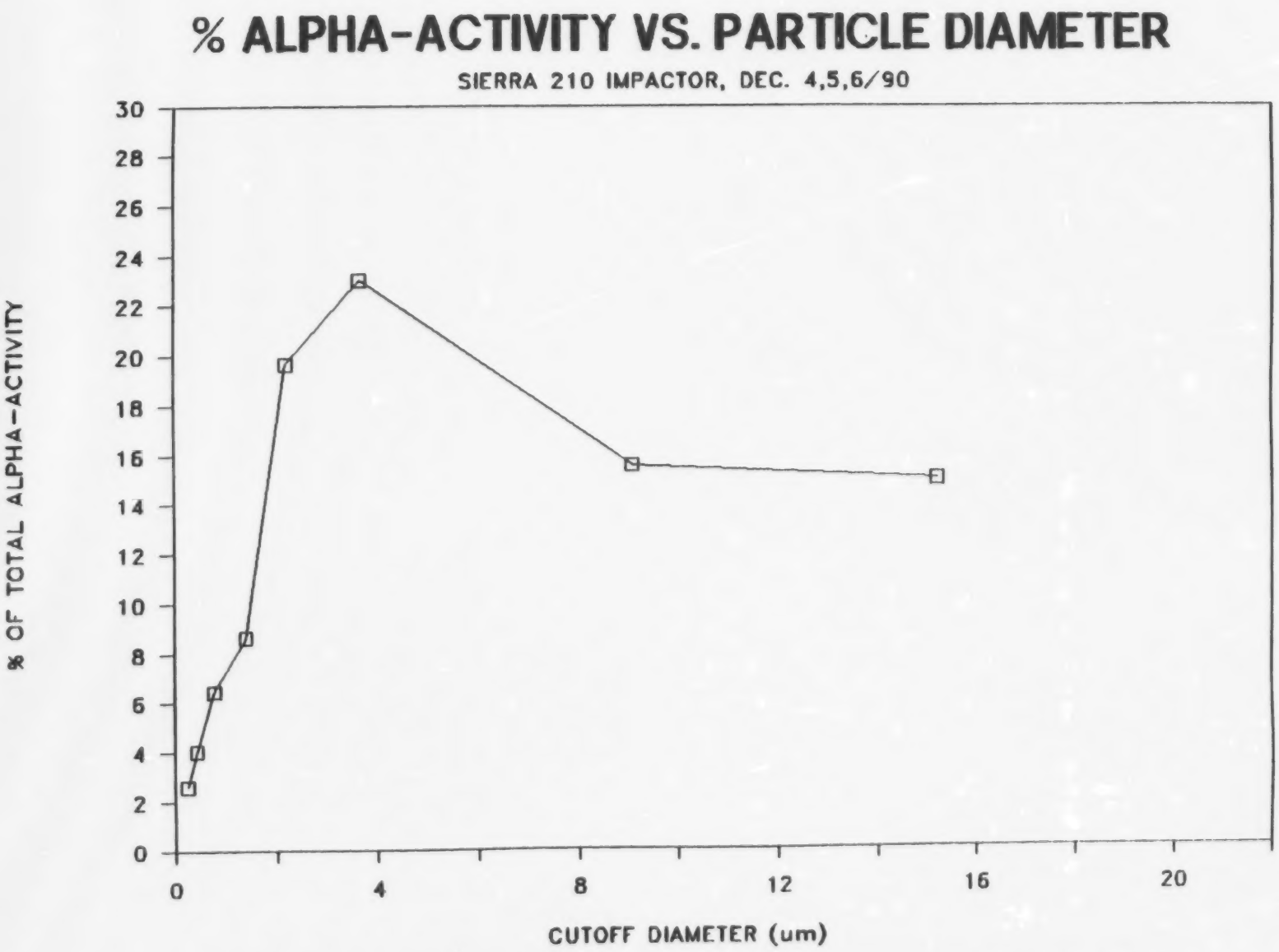


Fig. 42 - Percentage of total α-particle activity versus particle cut-off diameter.

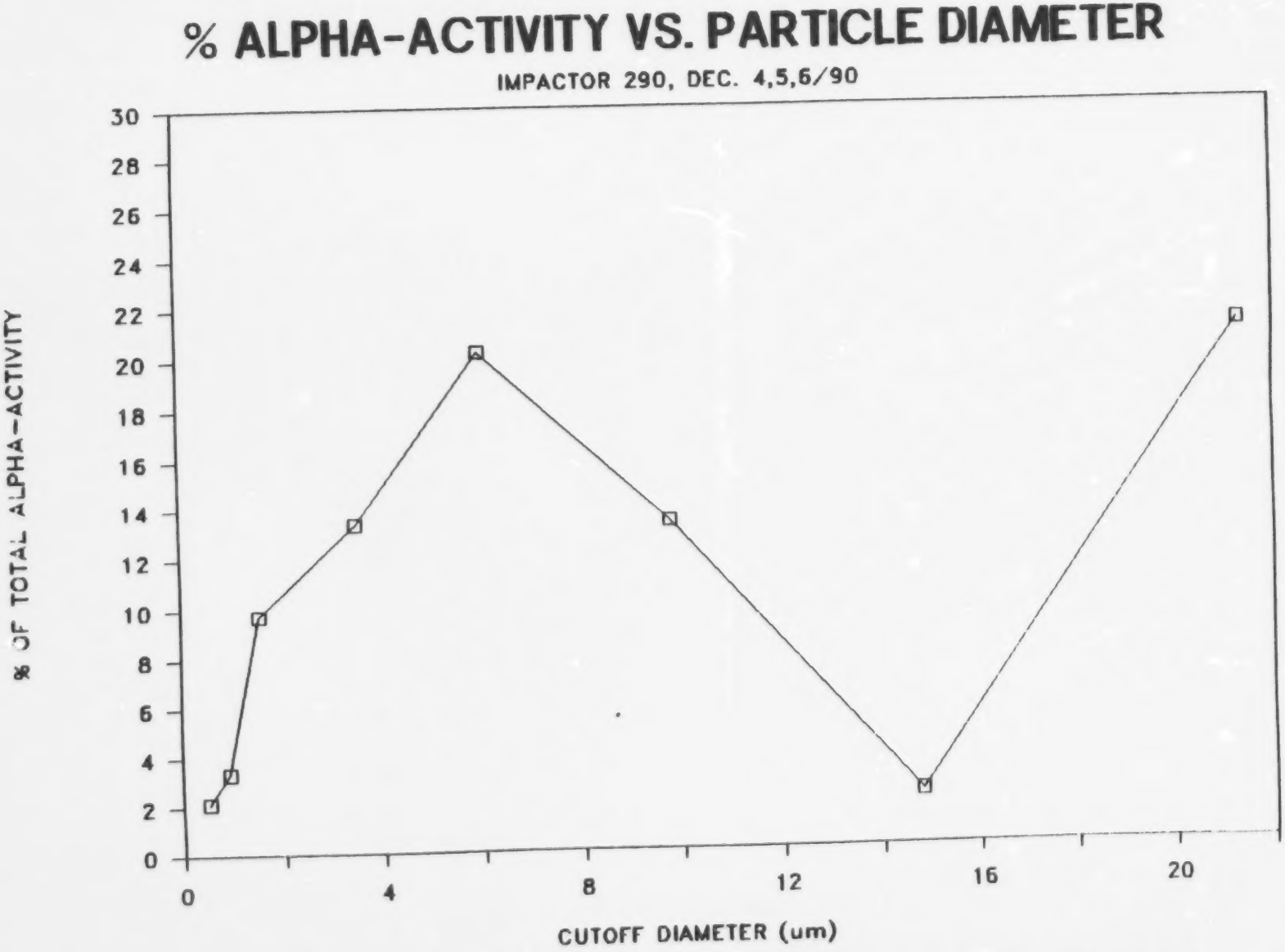


Fig. 43 - Percentage of total α-particle activity versus particle cut-off diameter.

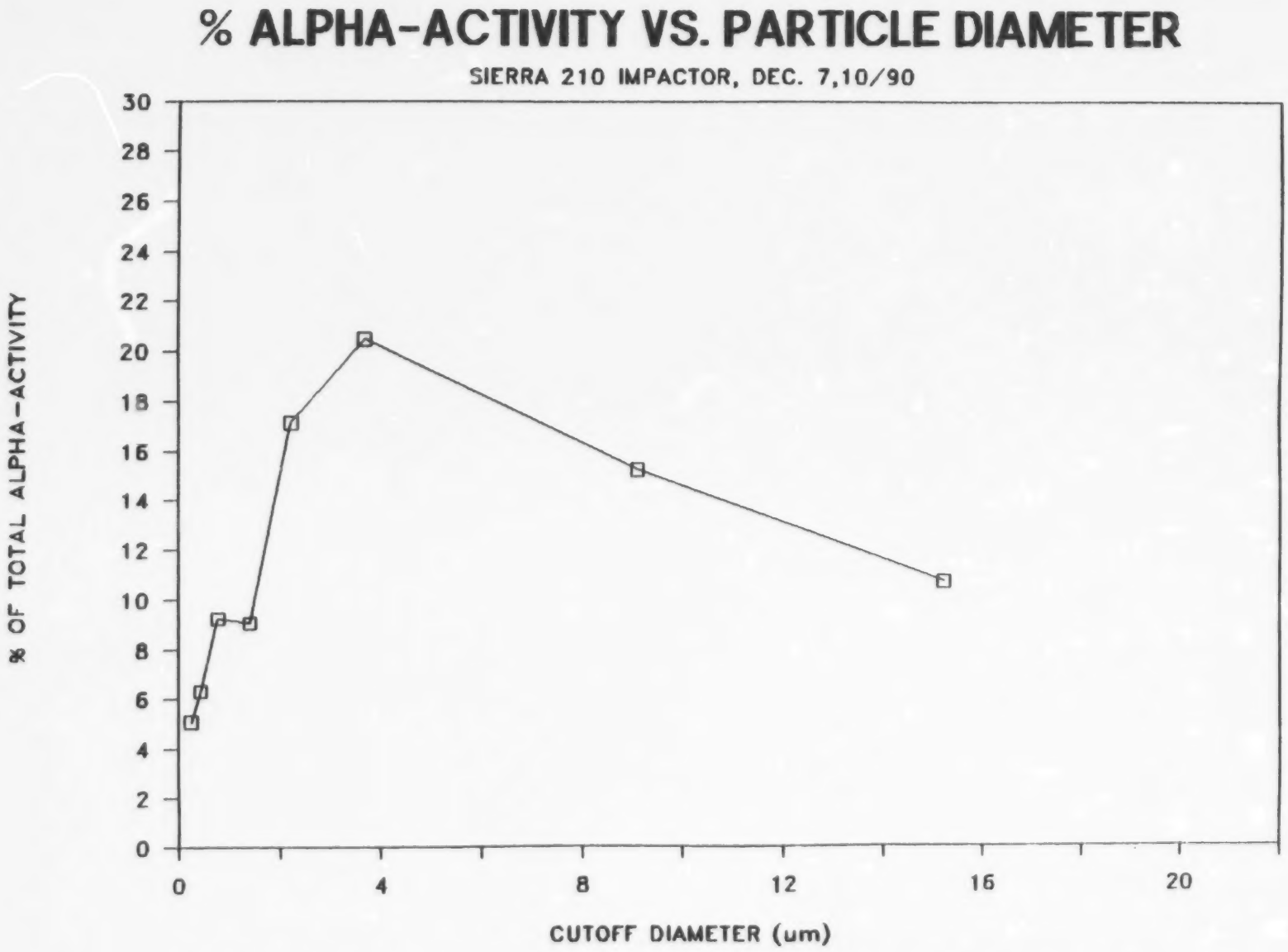


Fig. 44 - Percentage of total α-particle activity versus particle cut-off diameter.

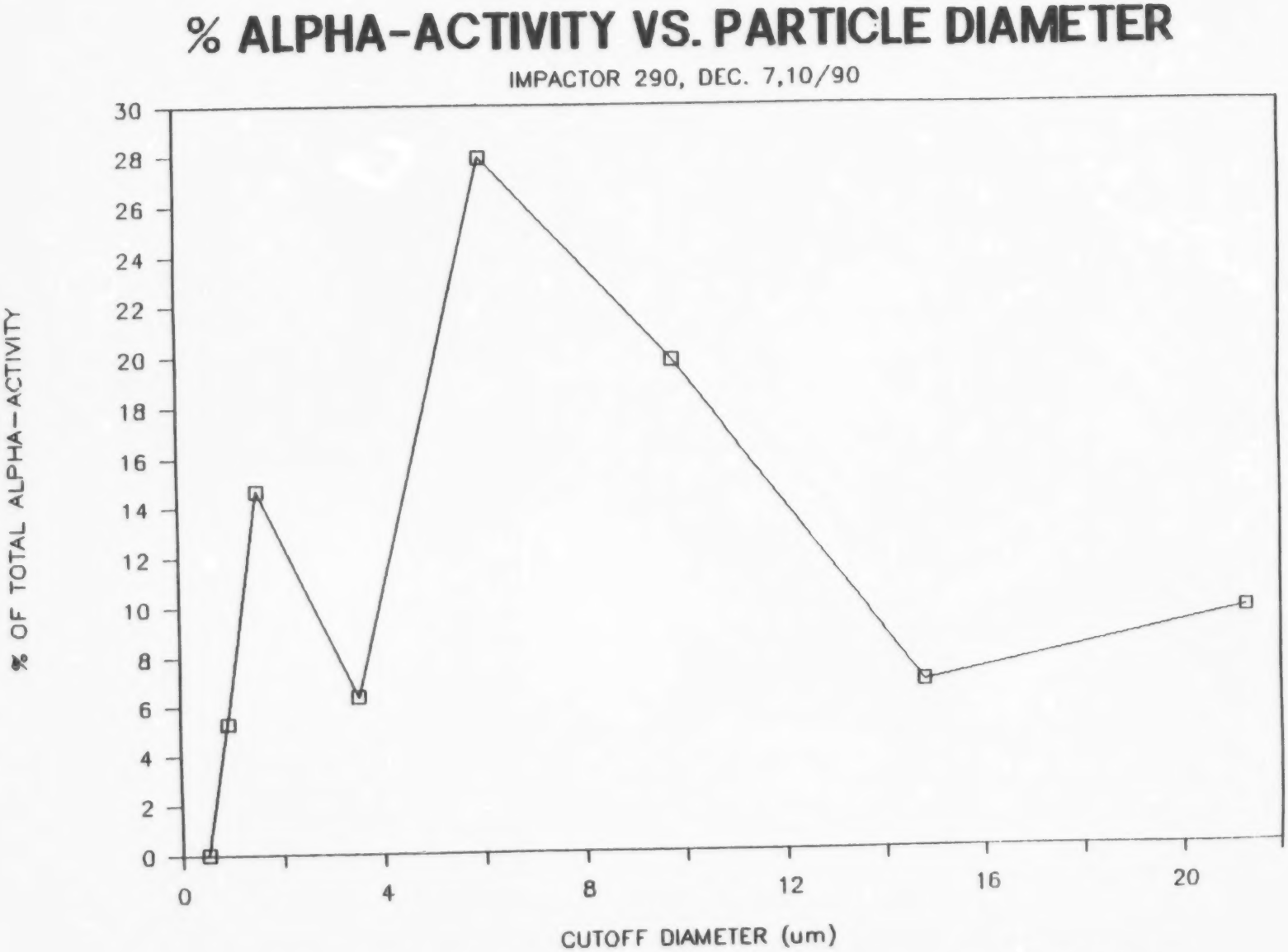


Fig. 45 - Percentage of total α-particle activity versus particle cut-off diameter.

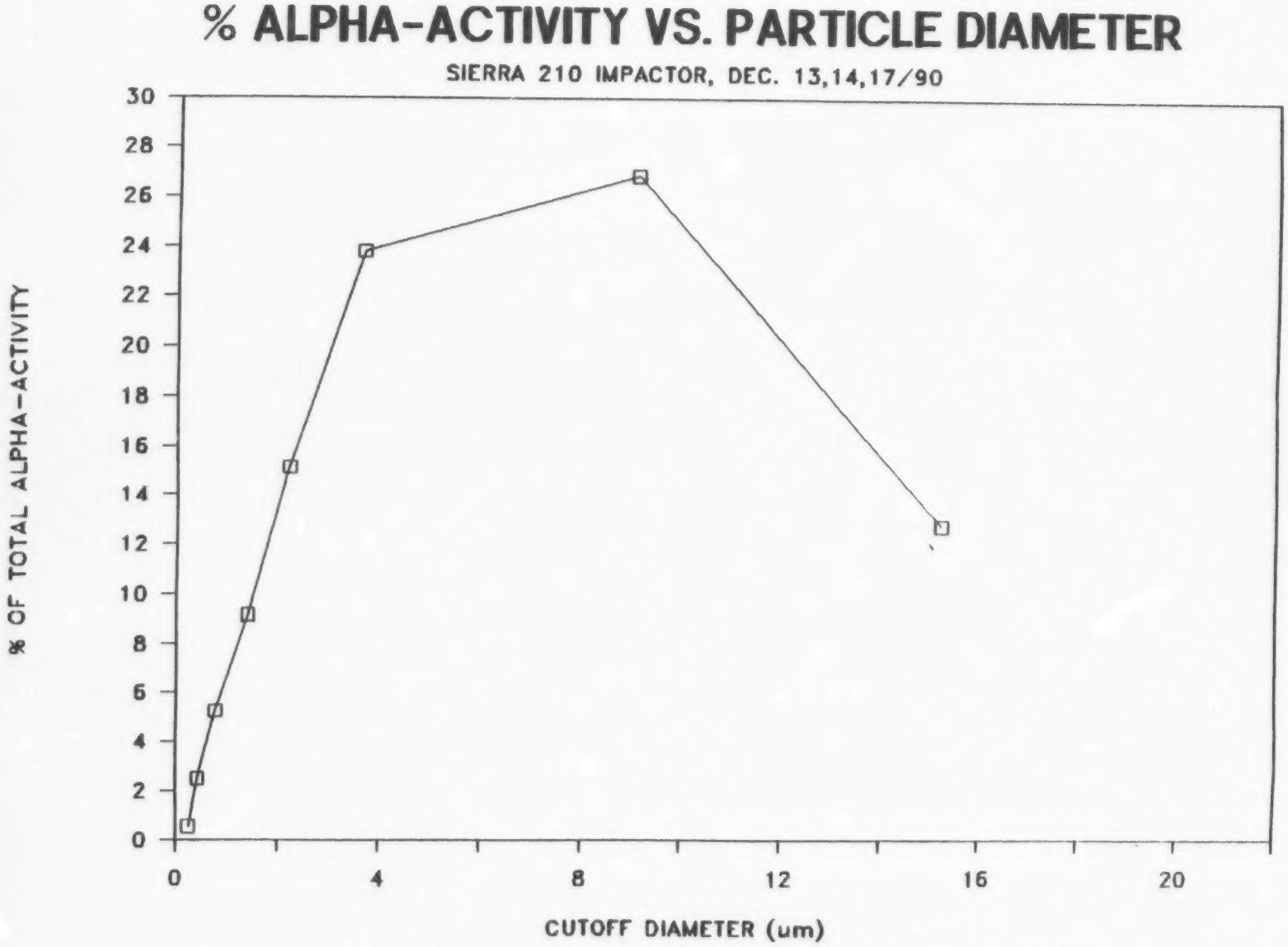


Fig. 46 - Percentage of total α-particle activity versus particle cut-off diameter.

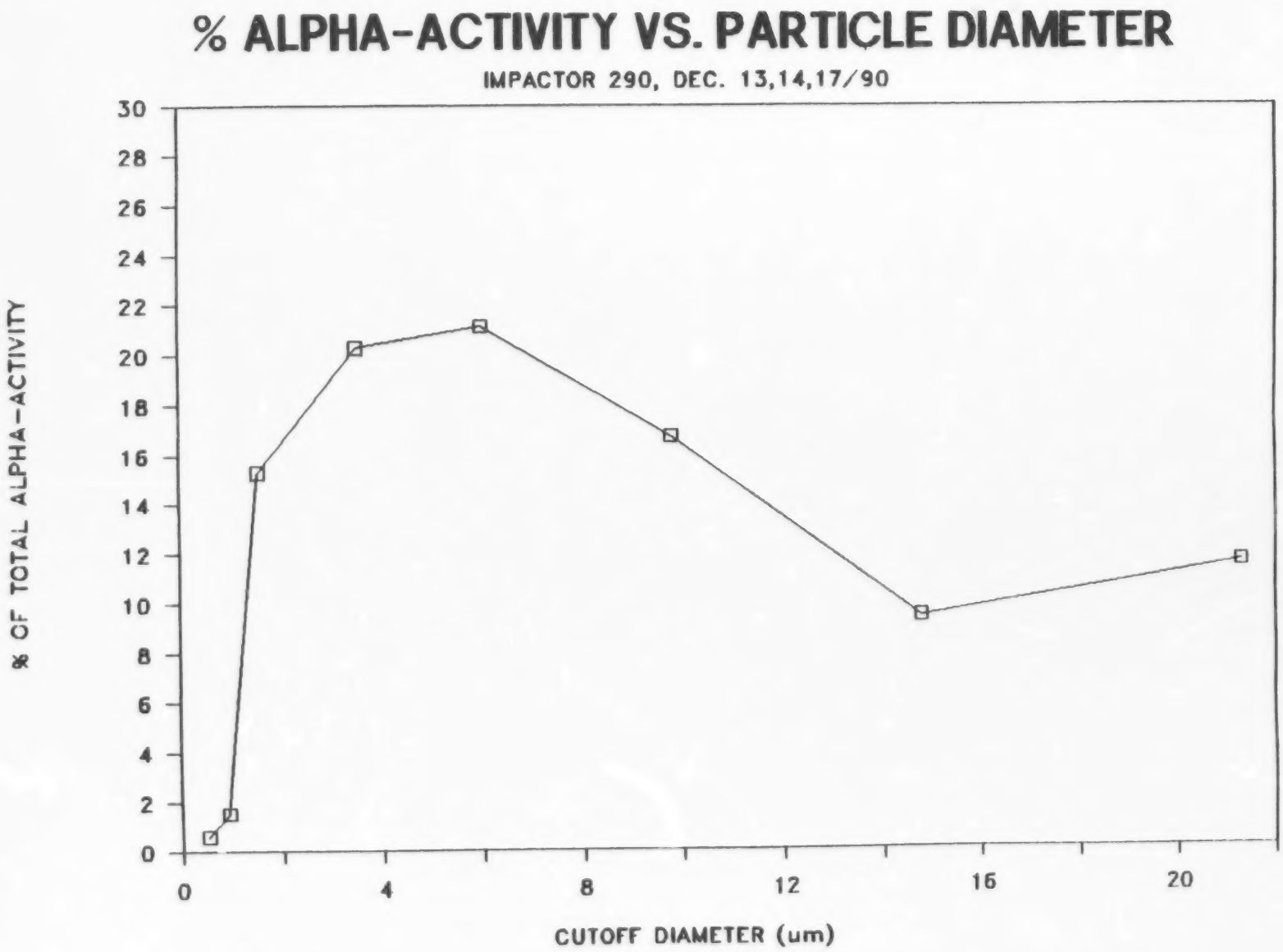


Fig. 47 - Percentage of total α-particle activity versus particle cut-off diameter.

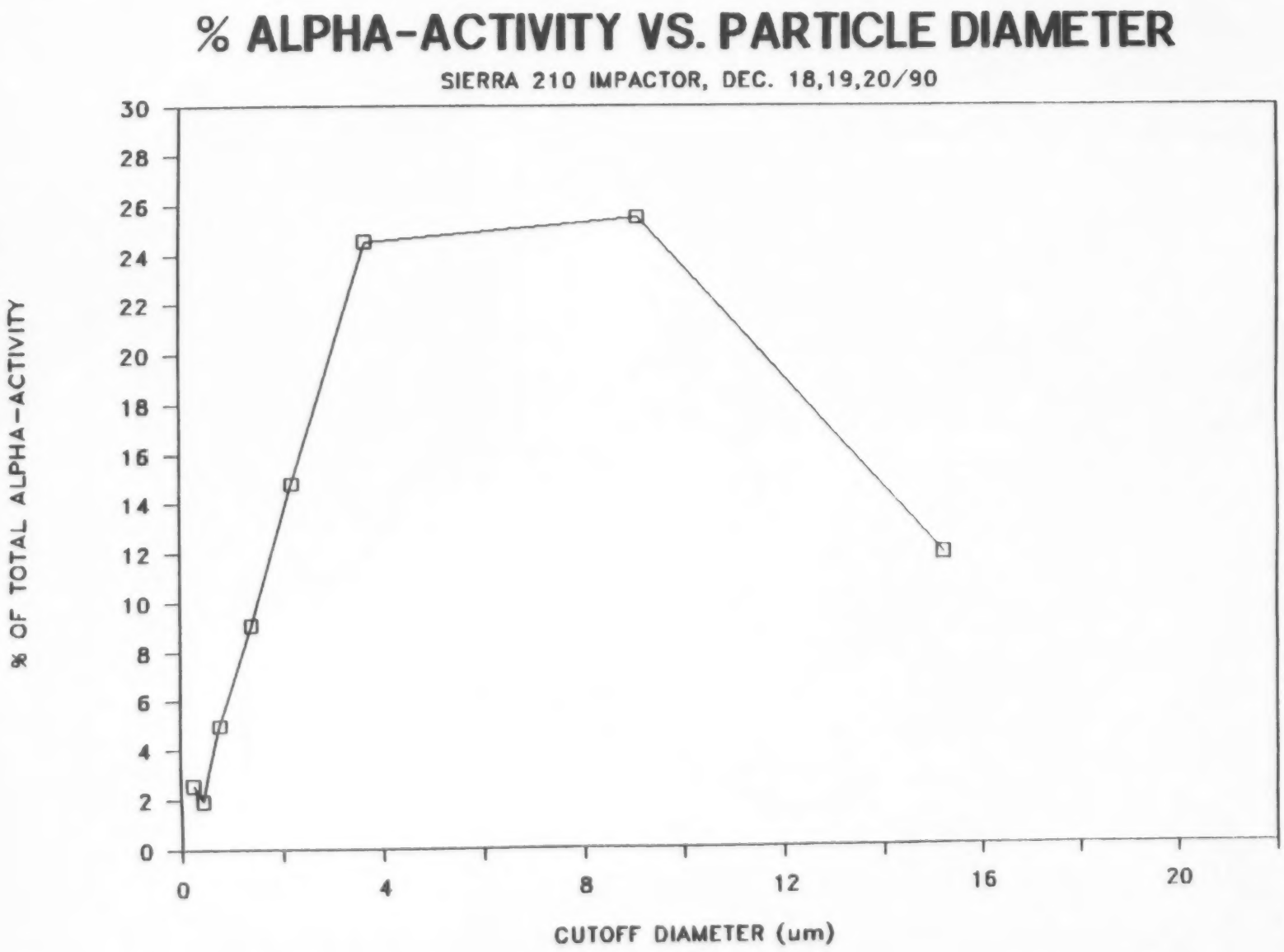


Fig. 48 - Percentage of total α-particle activity versus particle cut-off diameter.

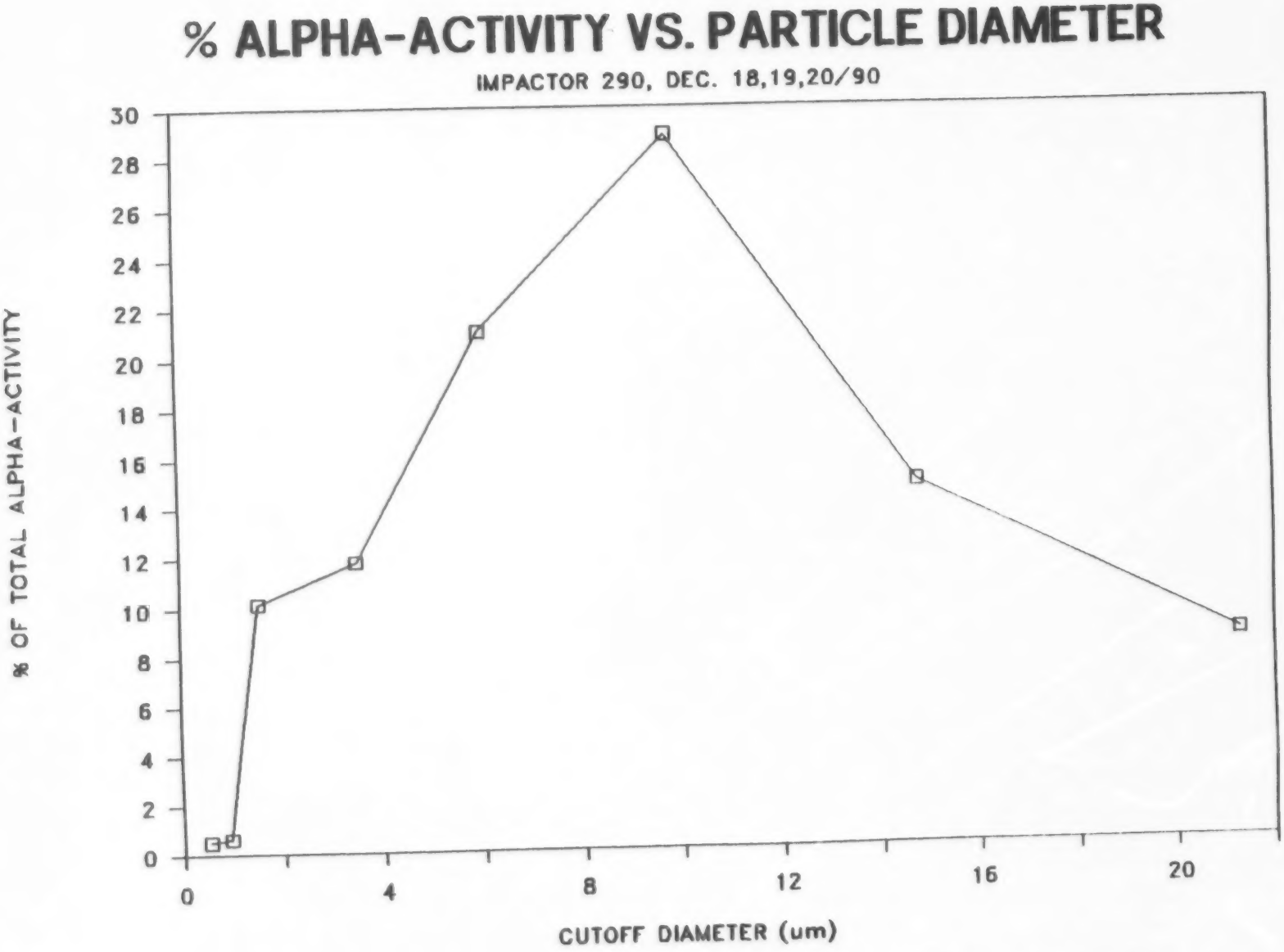


Fig. 49 - Percentage of total α-particle activity versus particle cut-off diameter.

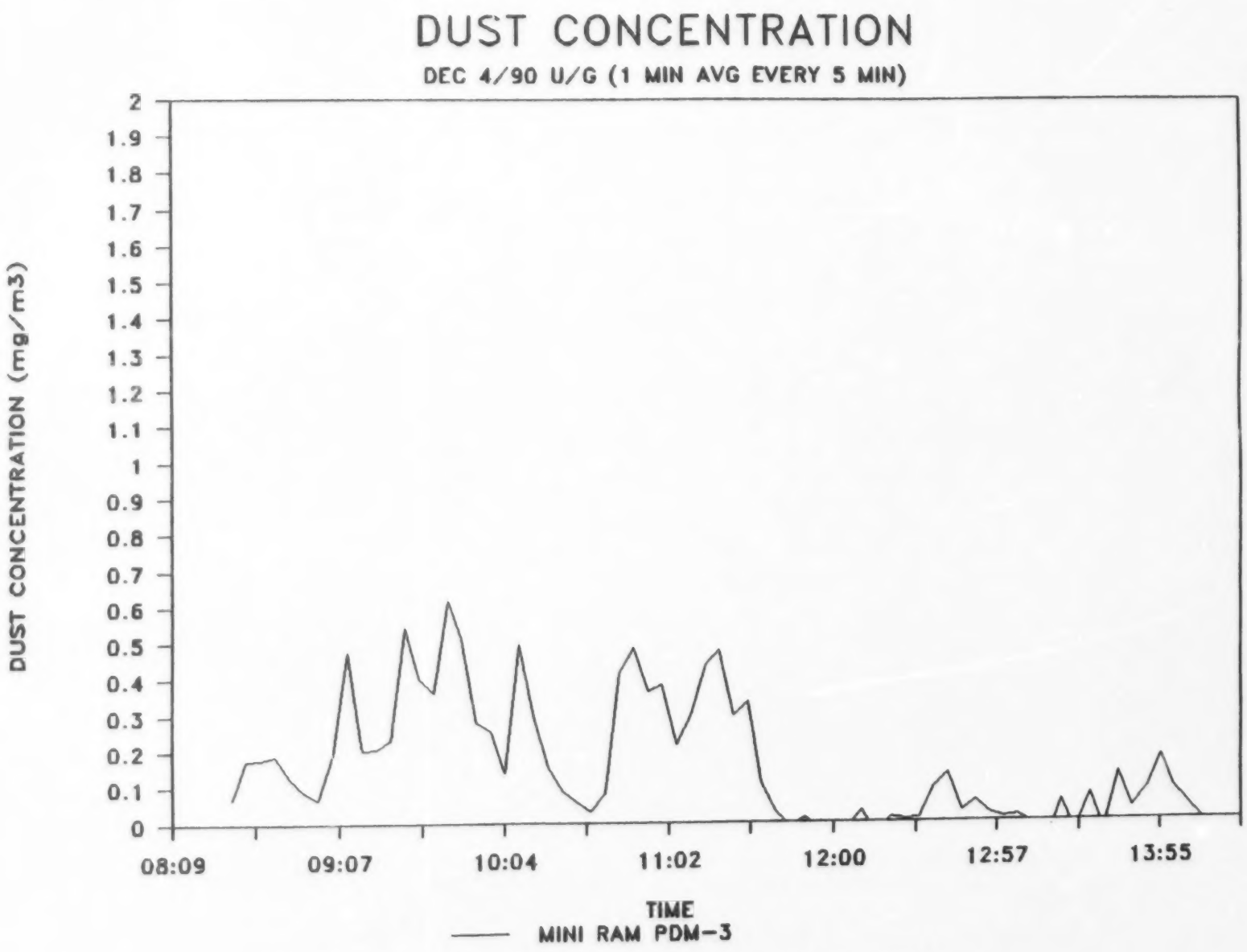


Fig. 50 - Dust mass concentration versus time for the MiniRam.

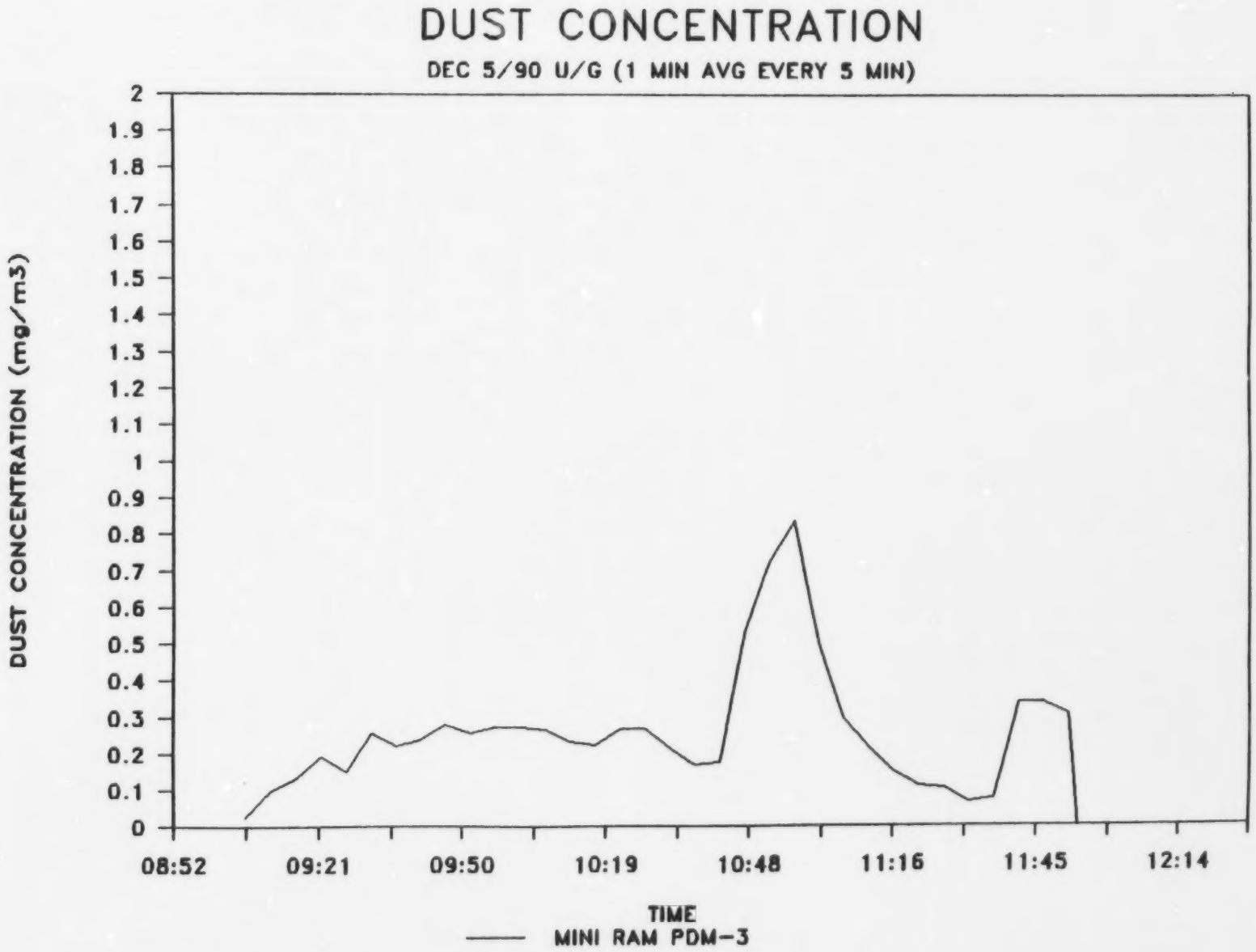


Fig. 51 - Dust mass concentration versus time for the MiniRam.

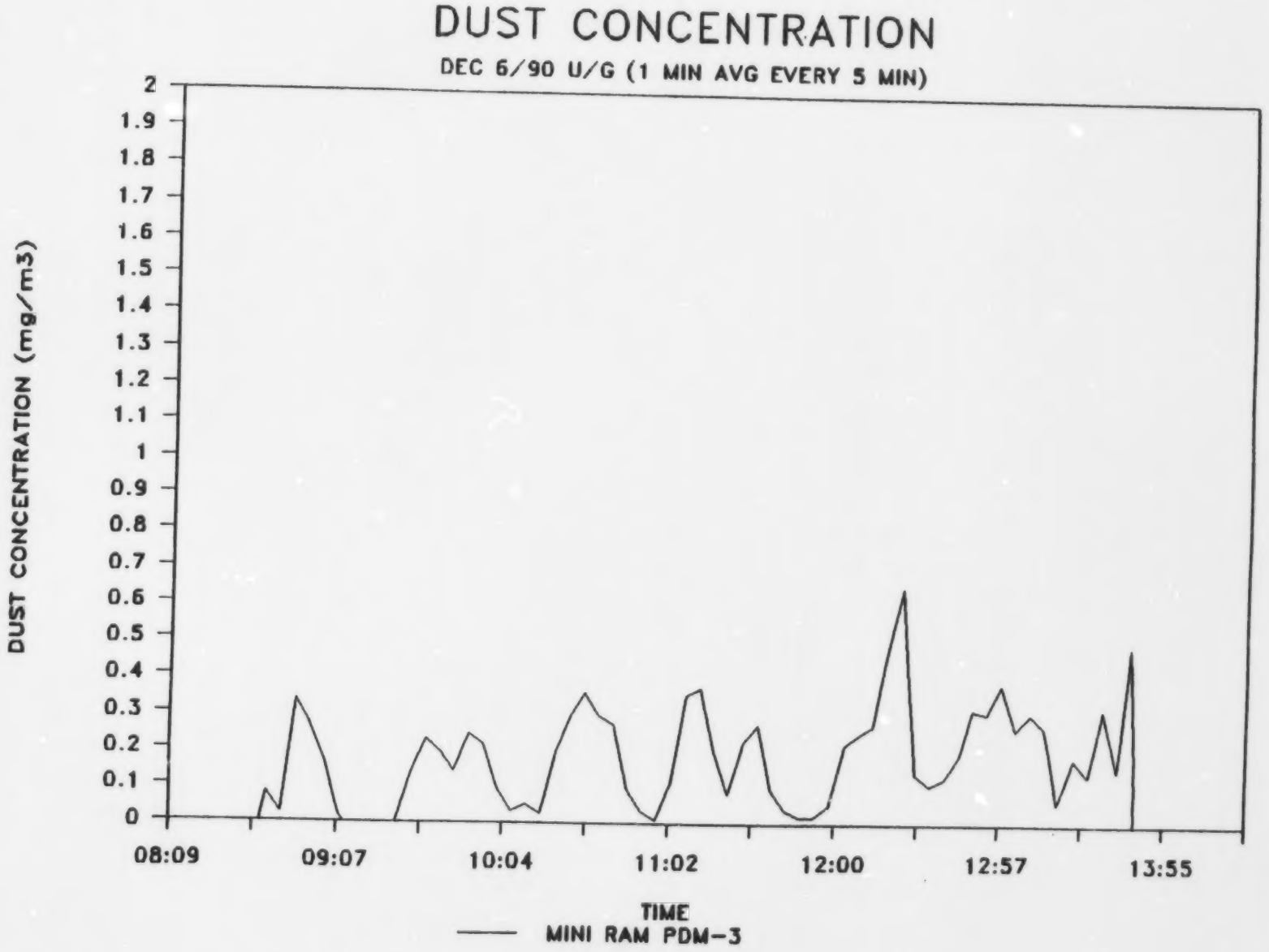


Fig. 52 - Dust mass concentration versus time for the MiniRam.

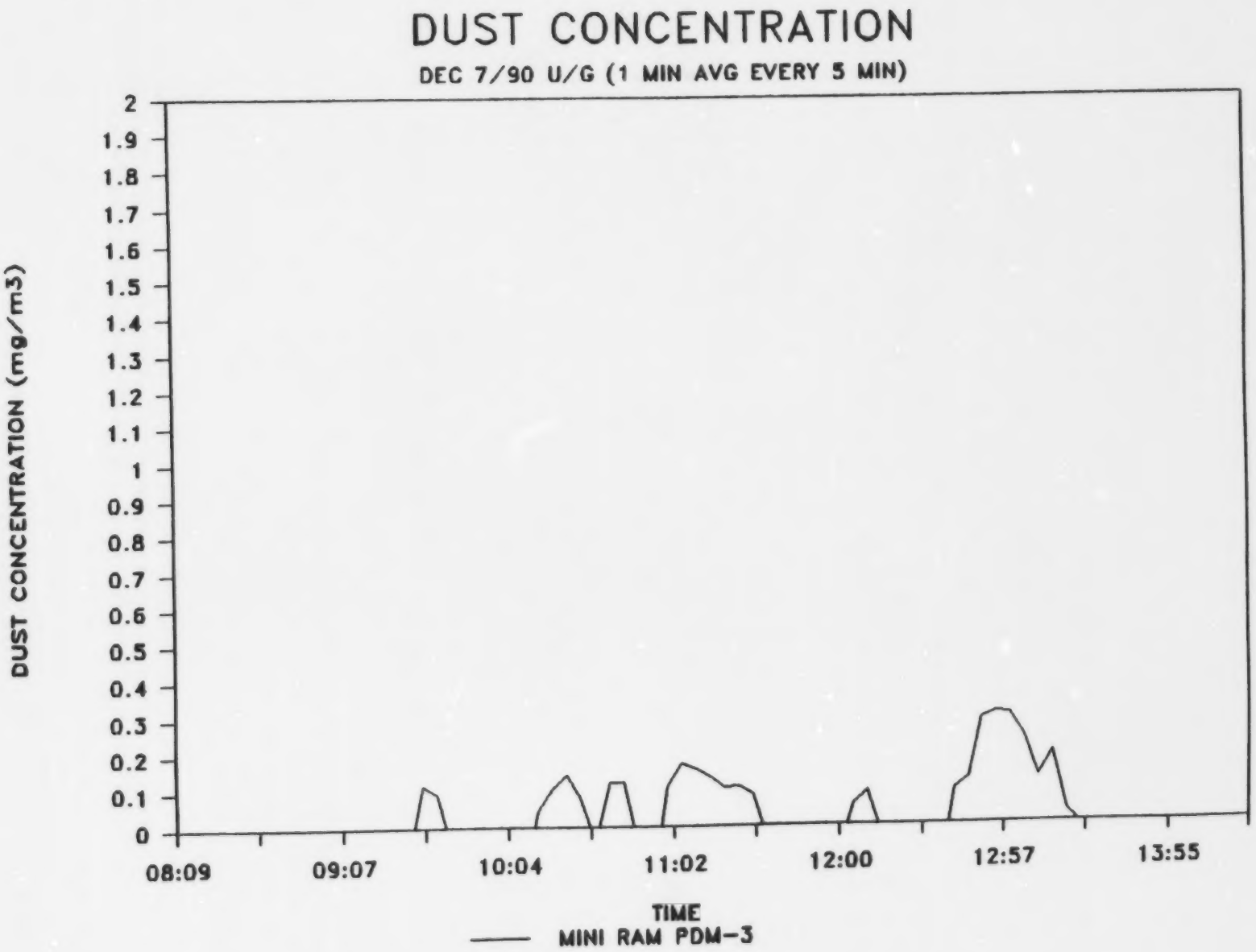


Fig. 53 - Dust mass concentration versus time for the MiniRam.

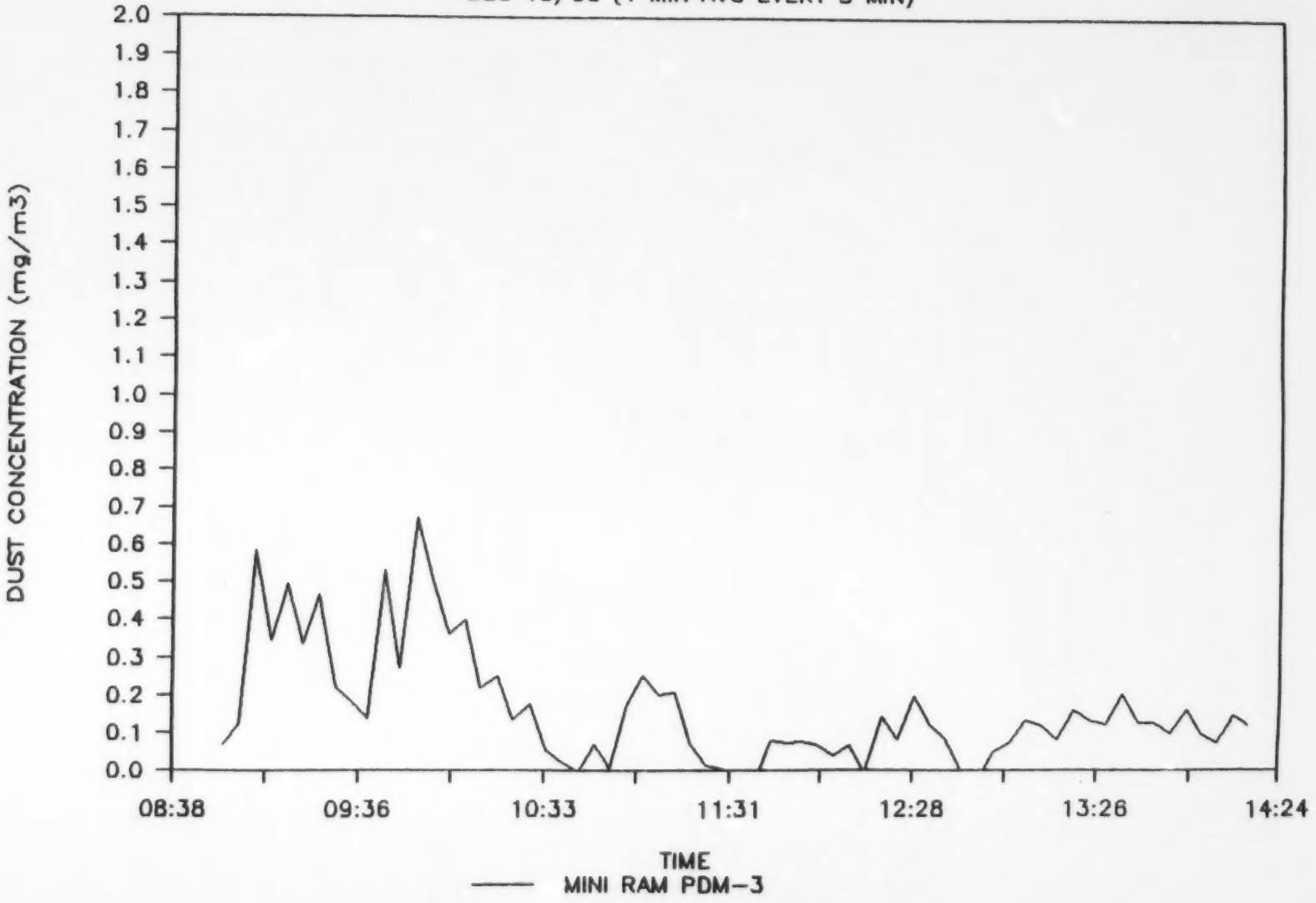


Fig. 54 - Dust mass concentration versus time for the MiniRam.

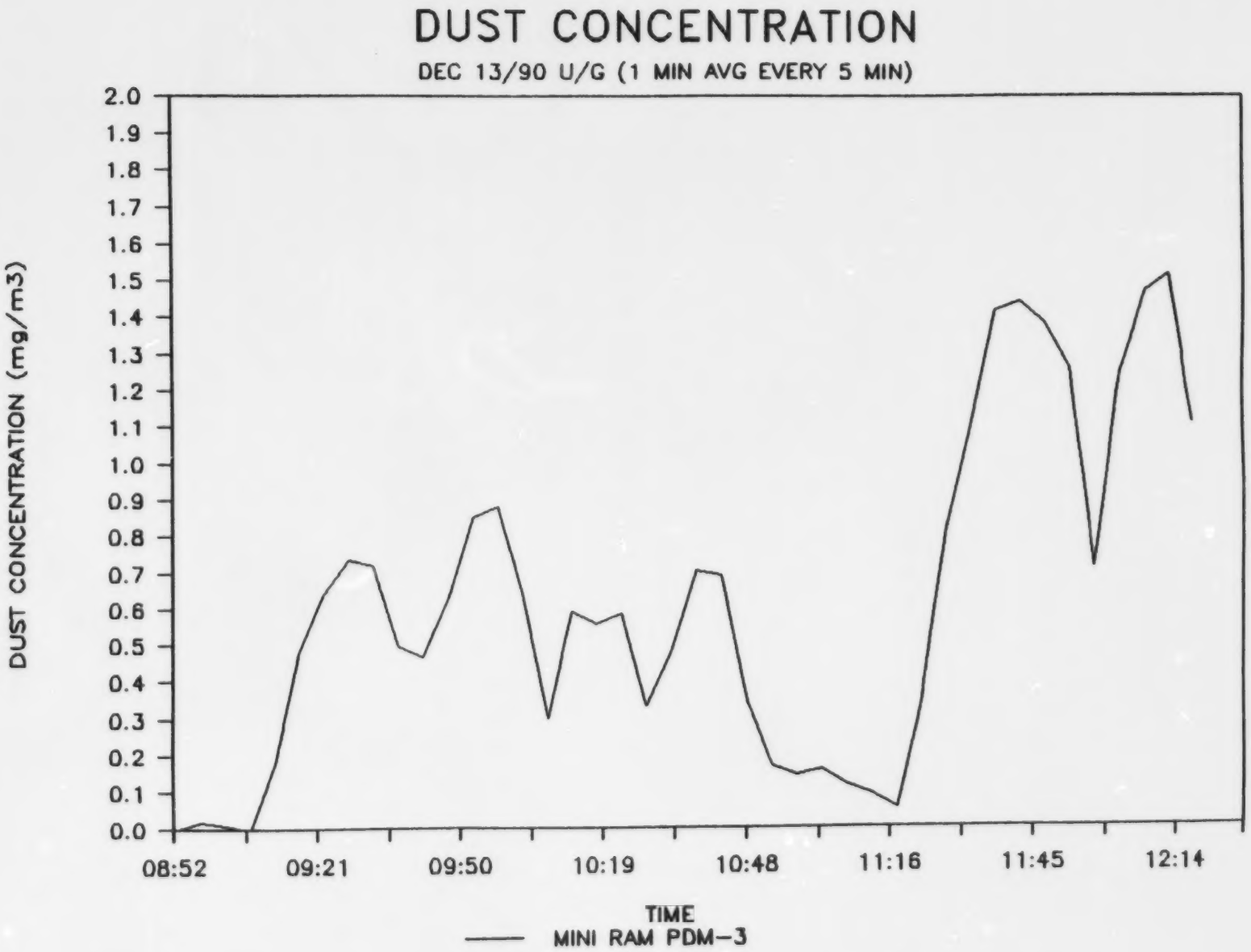


Fig. 55 - Dust mass concentration versus time for the MiniRam.

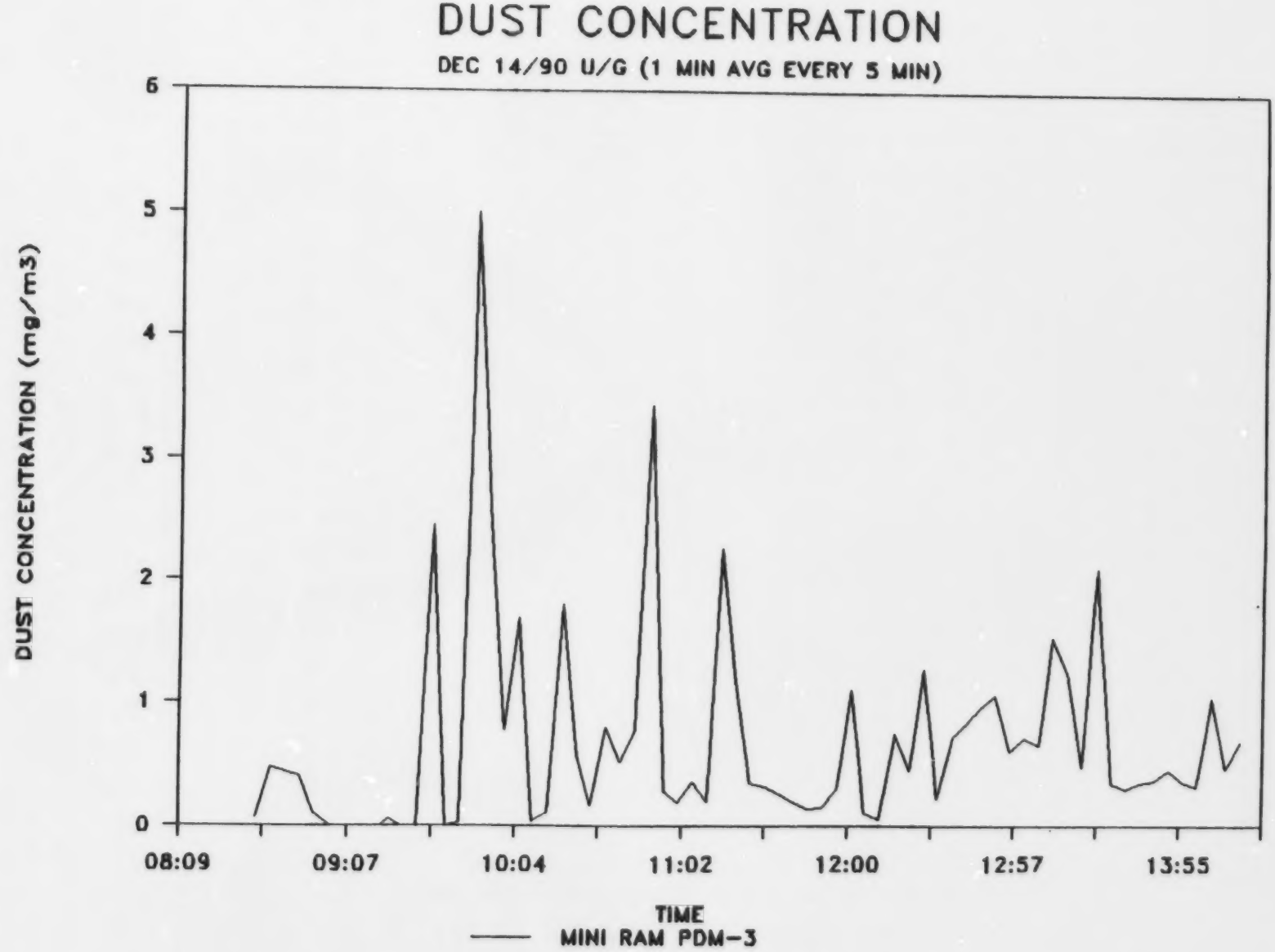


Fig. 56 - Dust mass concentration versus time for the MiniRam.

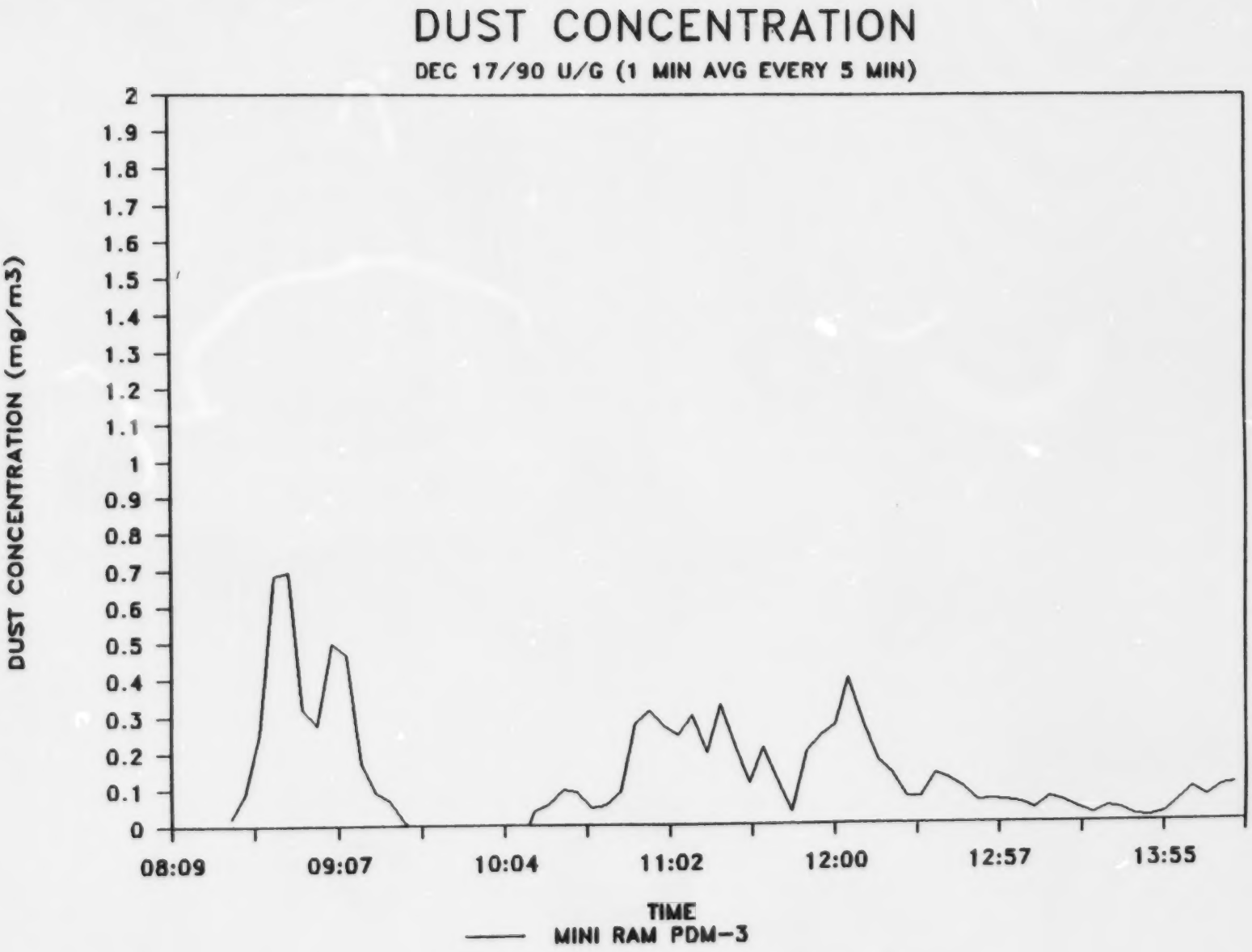


Fig. 57 - Dust mass concentration versus time for the MiniRam.

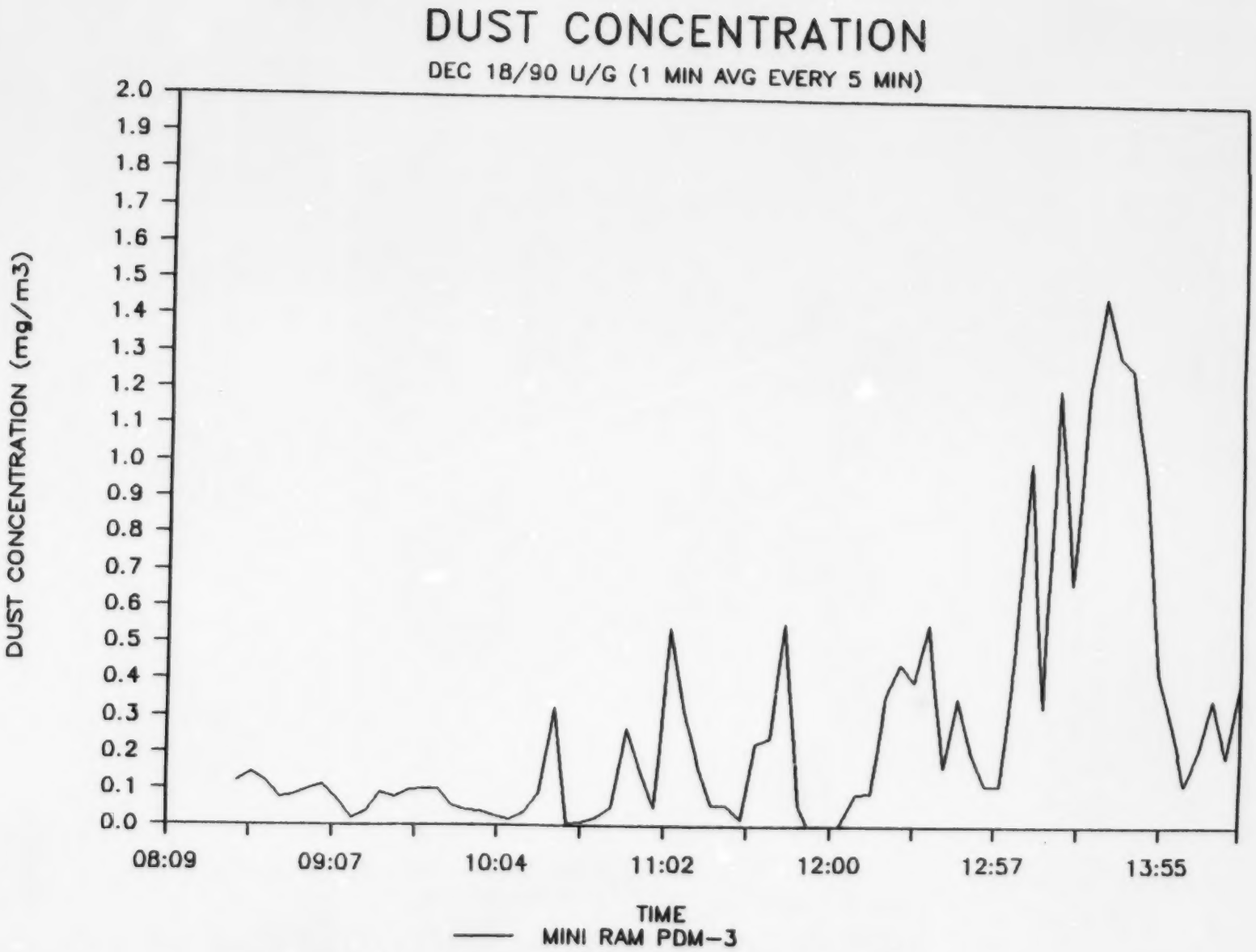


Fig. 58 - Dust mass concentration versus time for the MiniRam.

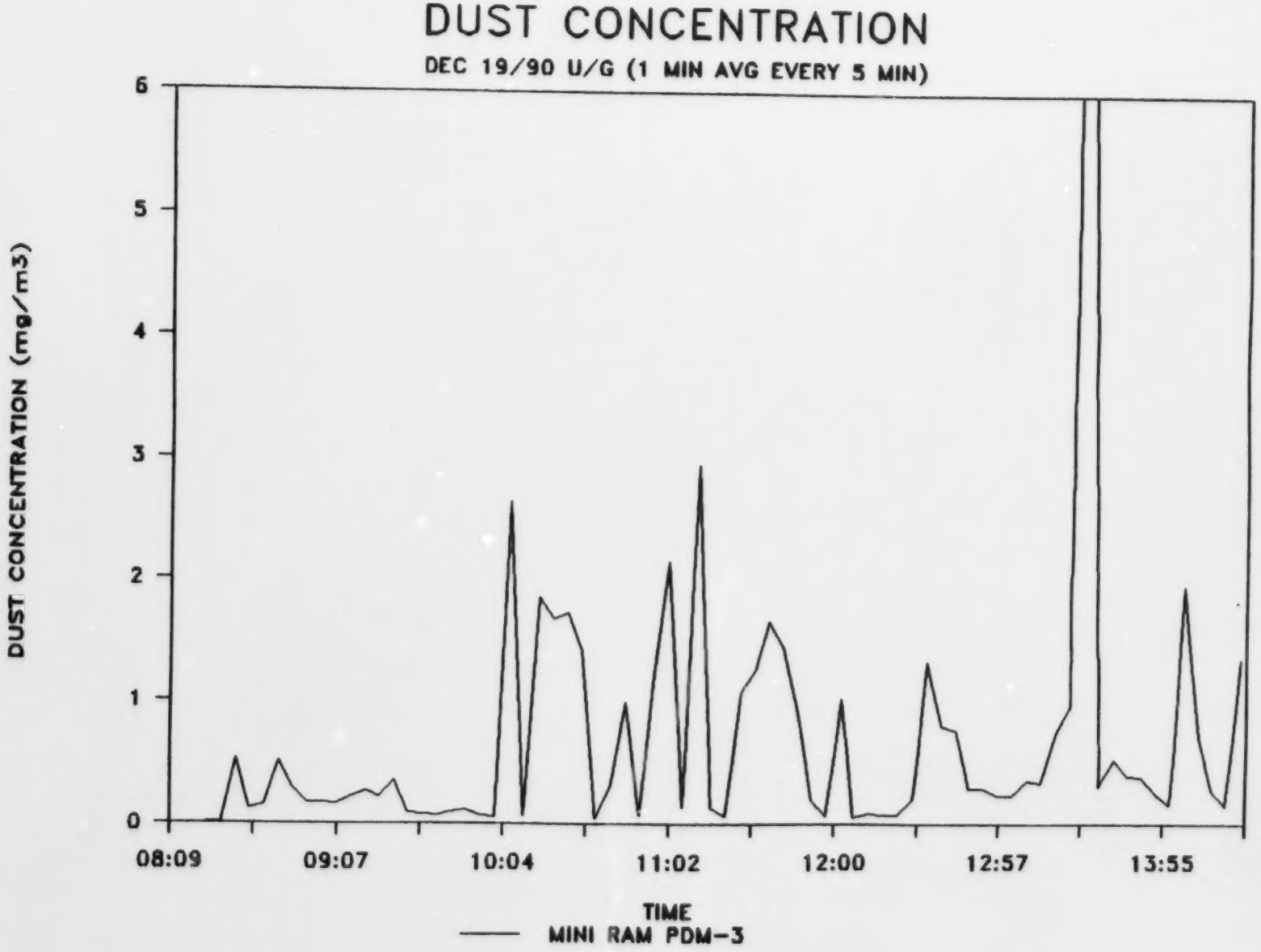


Fig. 59 - Dust mass concentration versus time for the MiniRam.

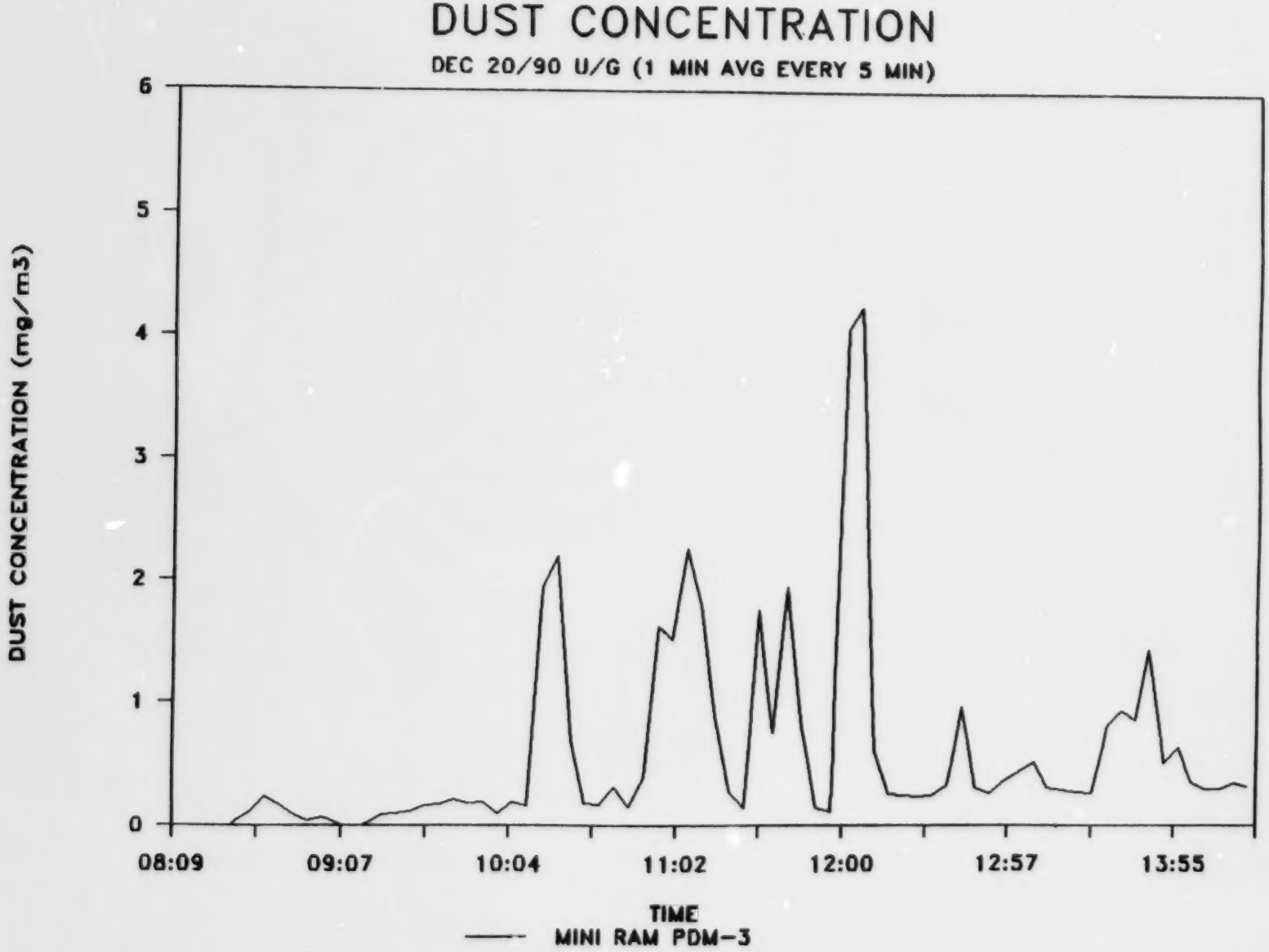


Fig. 60 - Dust mass concentration versus time for the MiniRam.

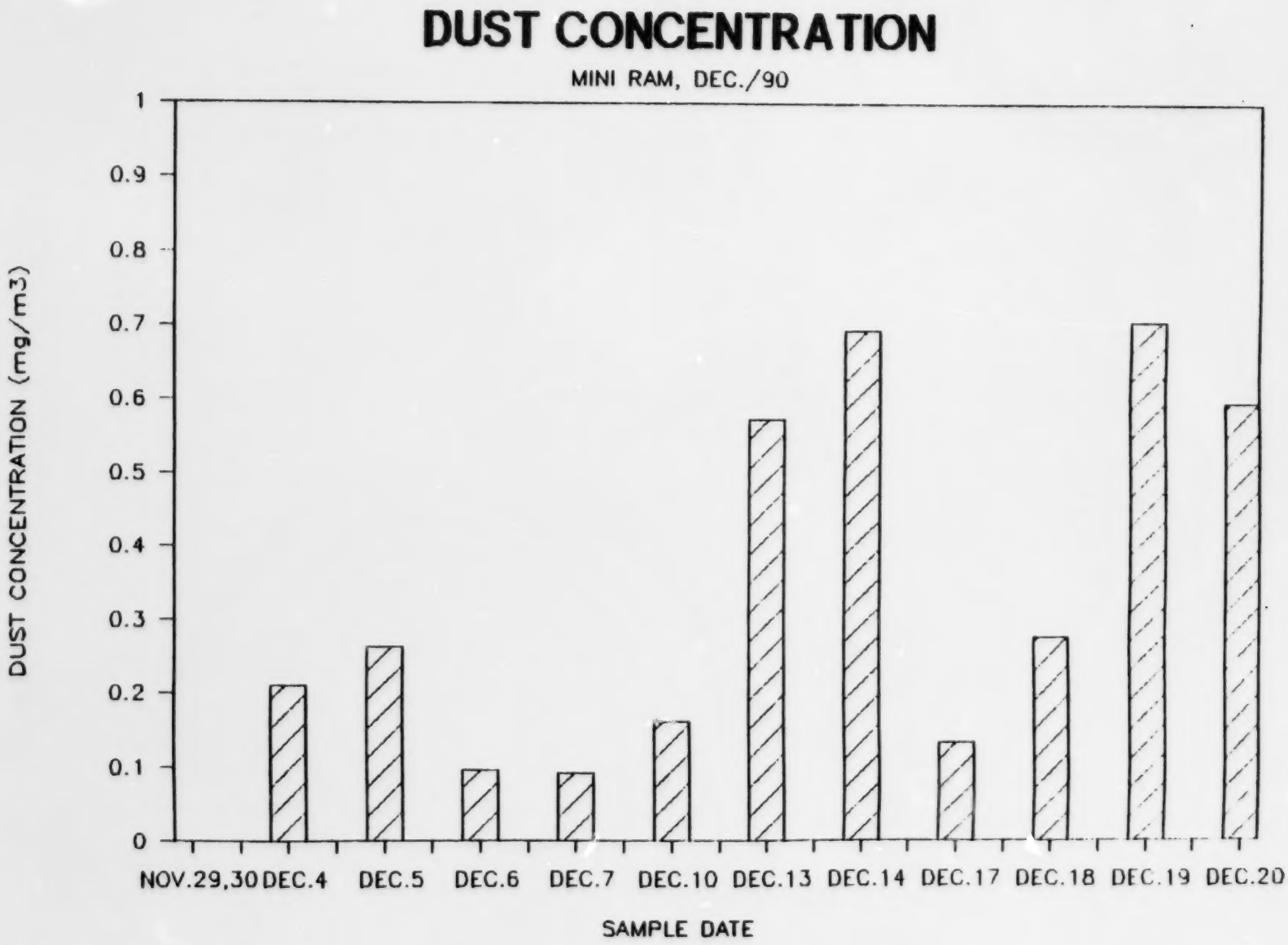


Fig. 61 - Average dust mass concentration versus sampling date measured with the MiniRam.

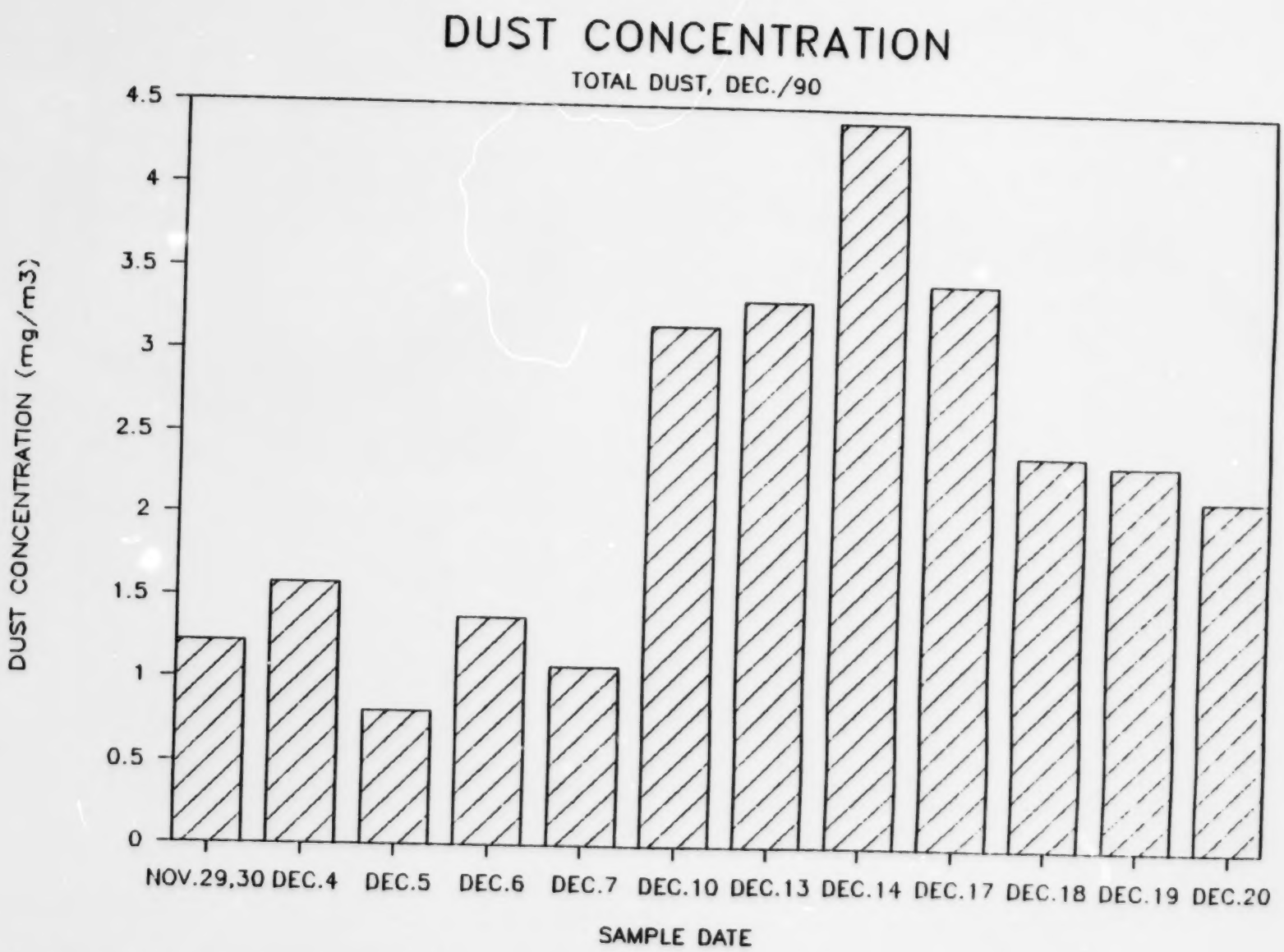


Fig. 62 - Average dust mass concentration versus sampling date obtained with the open face filter sampler (OFFS).

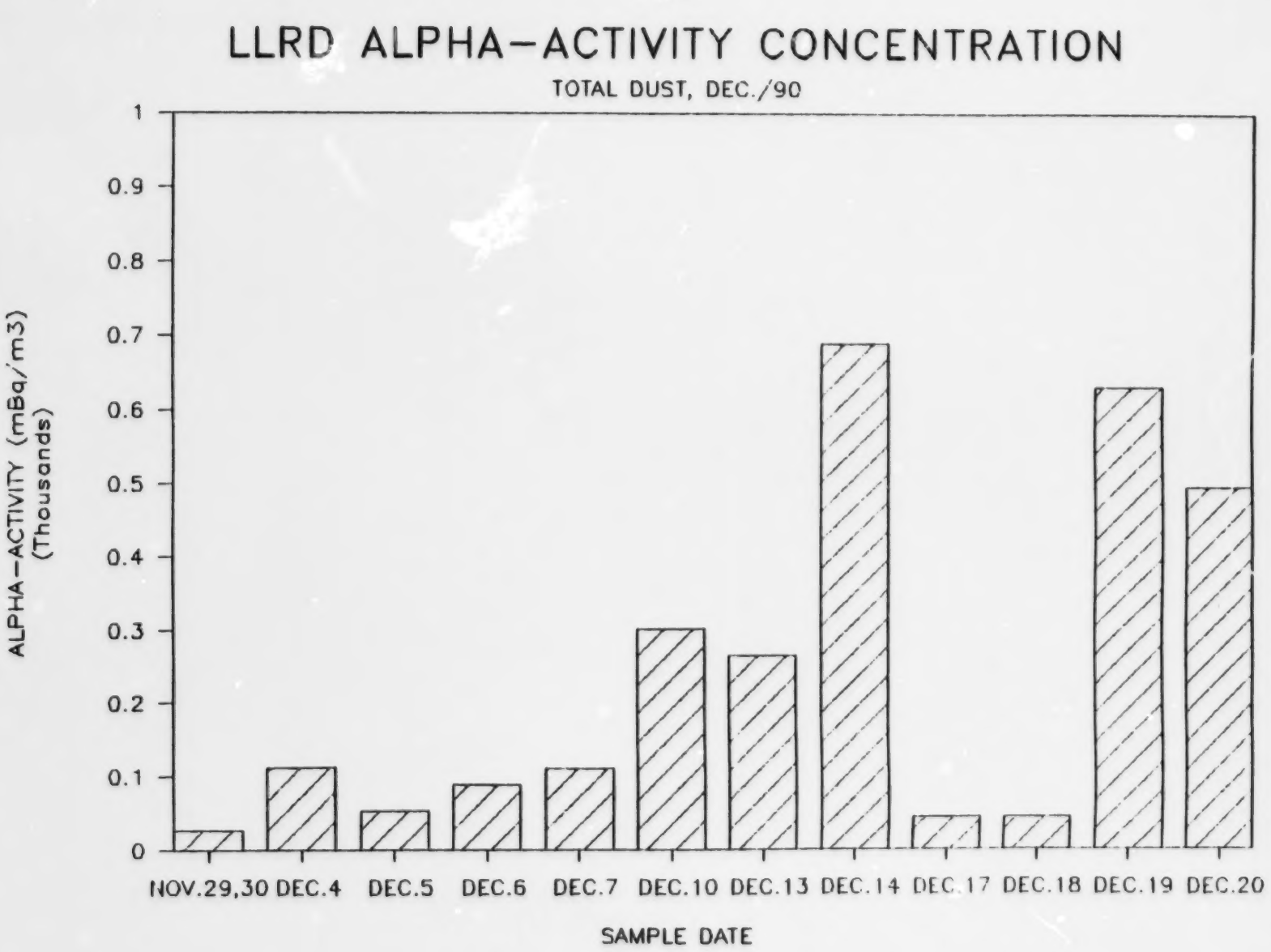


Fig. 63 - Average LLRD concentration versus sampling date using the OFFS.

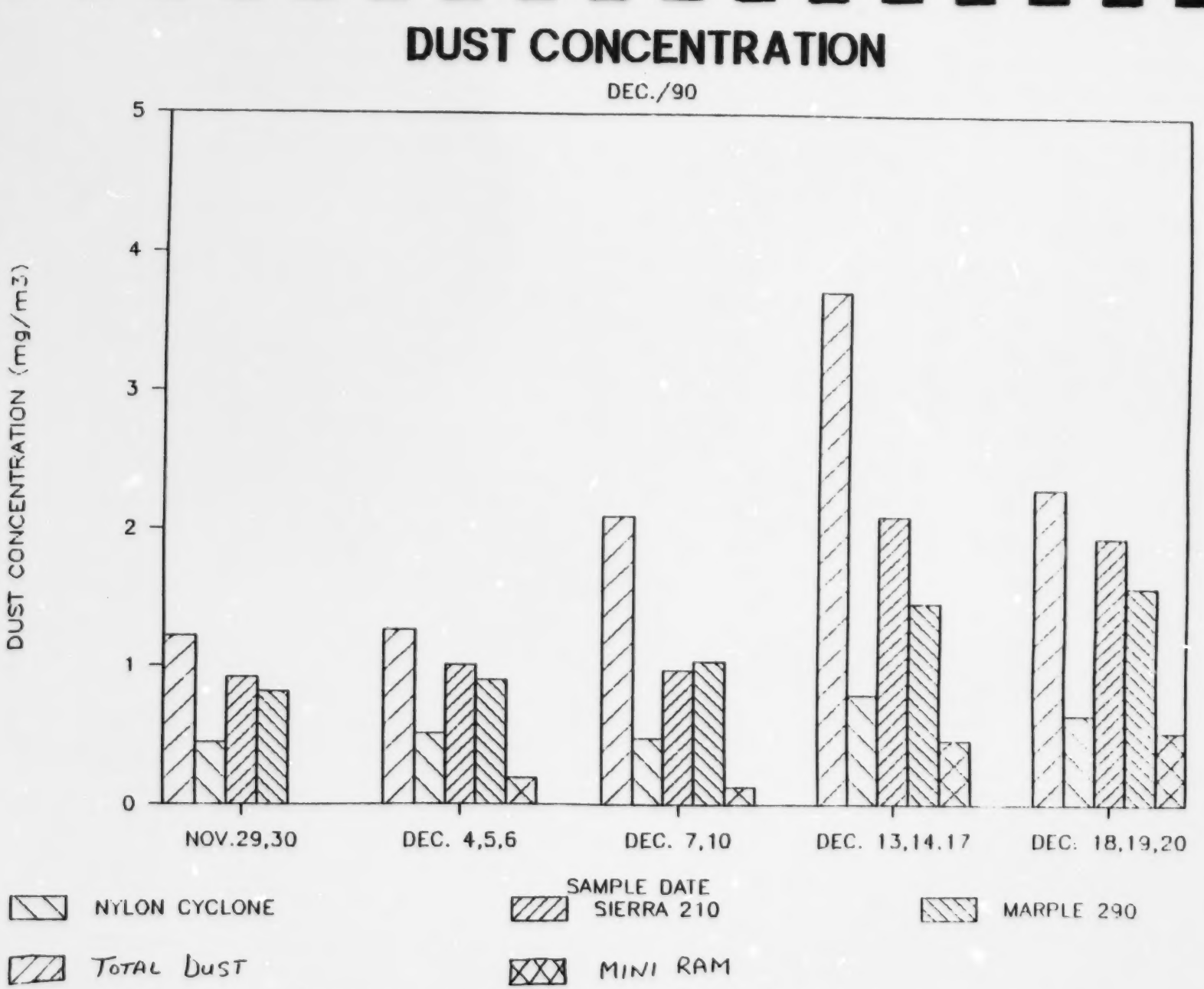


Fig. 64 - Comparison of the average dust mass concentrations obtained with several dust monitoring instruments for several sampling periods.

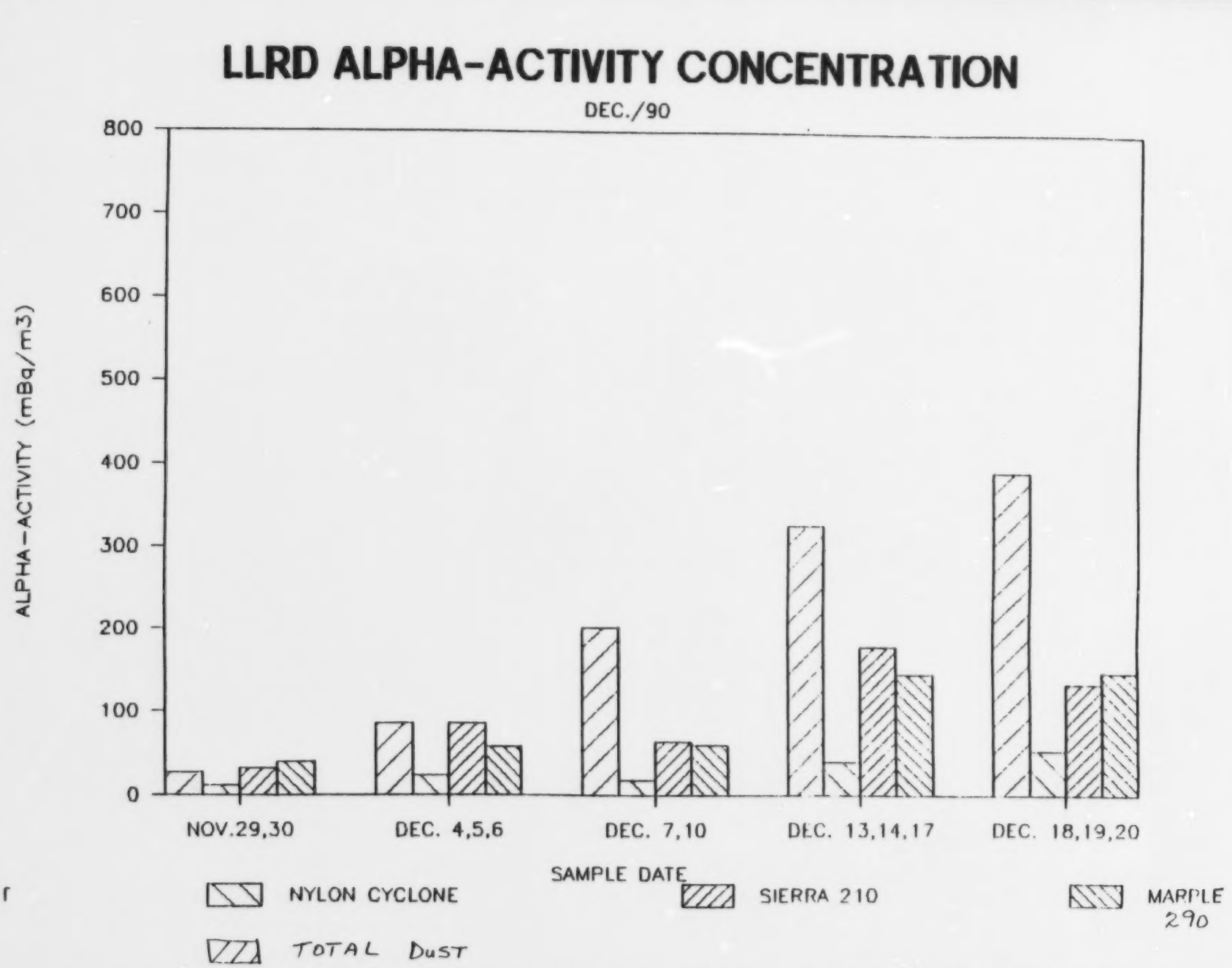


Fig. 65 - Comparison of the average [LLRD] obtained with several dust monitoring instruments for several sampling periods.

APPENDIX A

As previously indicated in sub-section 2 (page 10) entitled: "Dust Mass and α-Particle Activity Versus Particle Size Distribution", Figures A1 to A20 show similar data as Figures 30 to 49 but presented in a different way. These graphs, for each daily shift, have been arranged for simplicity of analysis in the following order. Percentage (%) of total dust mass versus particle size cut-off, and % of total α-particle activity versus particle size cut-off, for the Sierra 210, followed by similar graphs for the Marple 290.

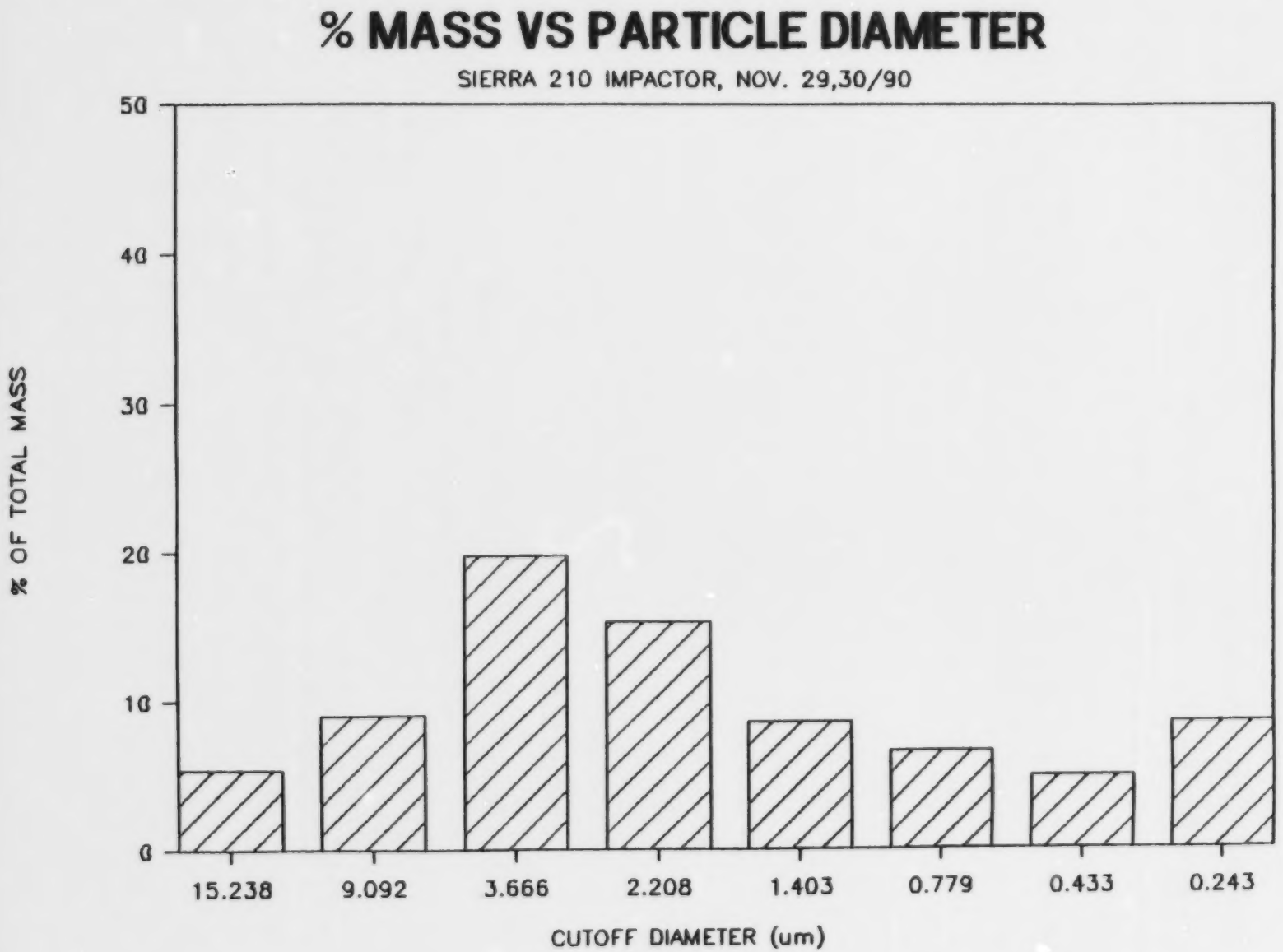


Fig. A1 - Percentage of the total dust mass versus cut-off diameter

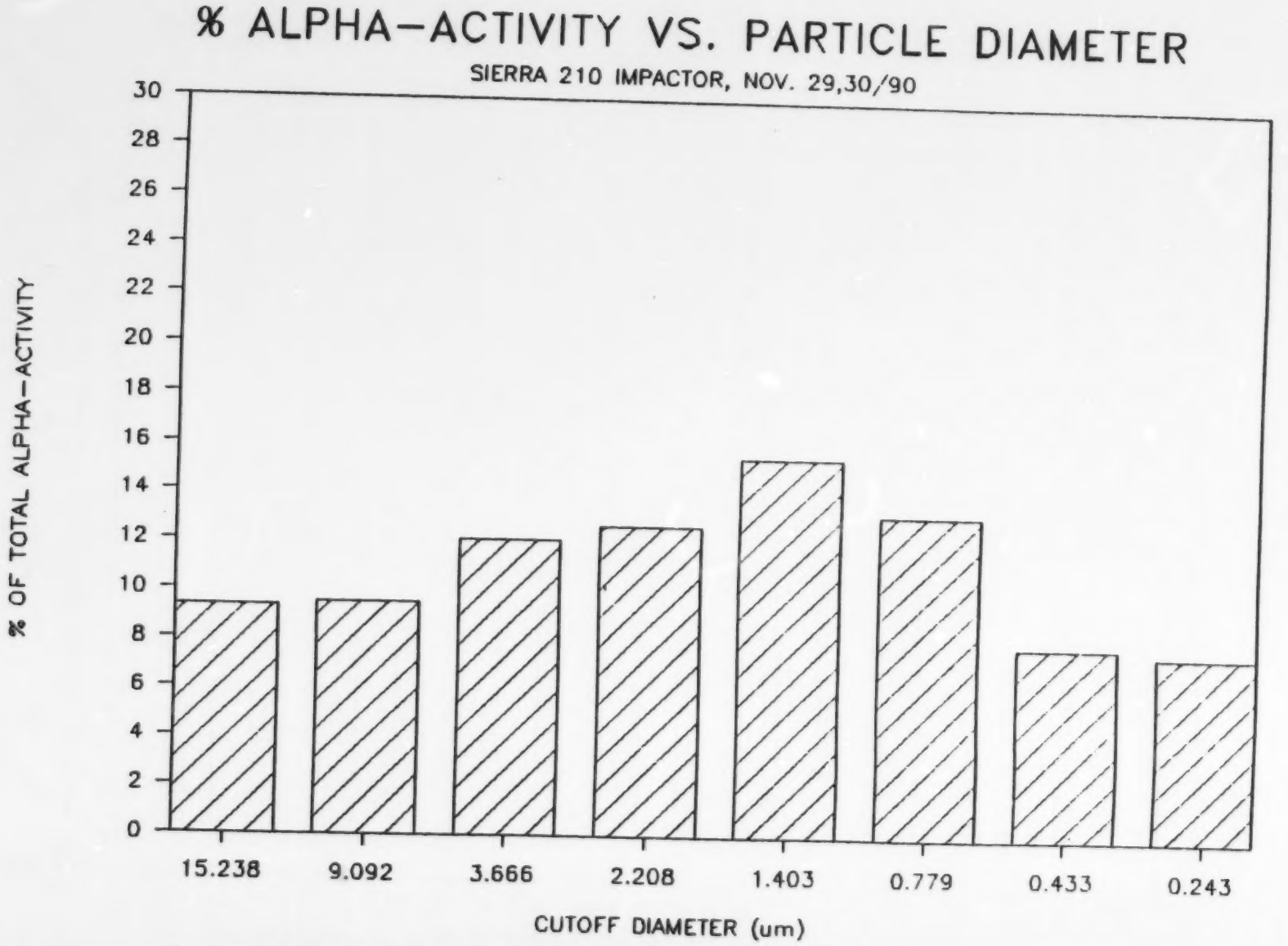


Fig. A2 - Percentage of the total α-particle activity versus cut-off diameter.

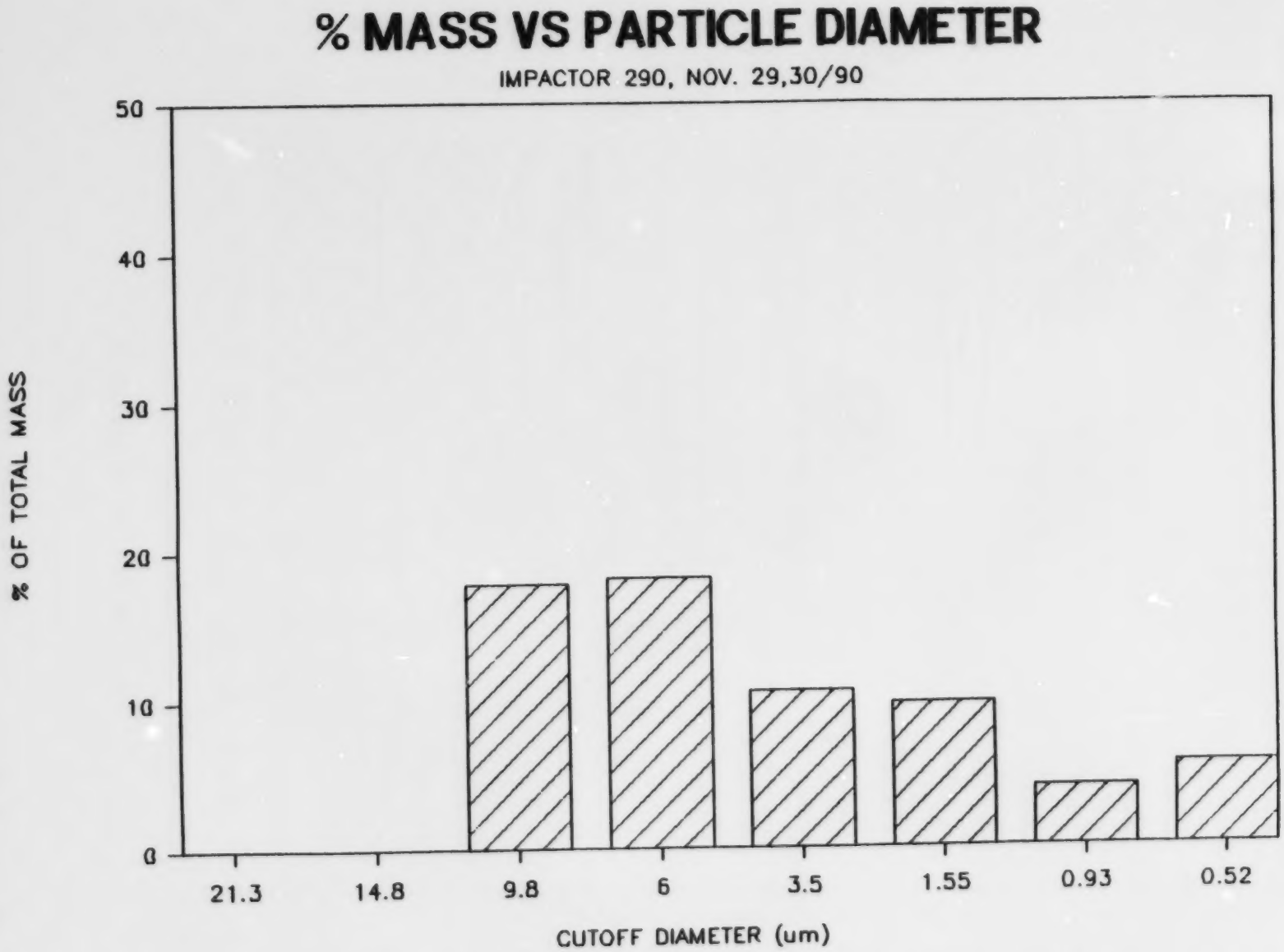


Fig. A3 - Percentage of the total dust mass versus cut-off diameter.

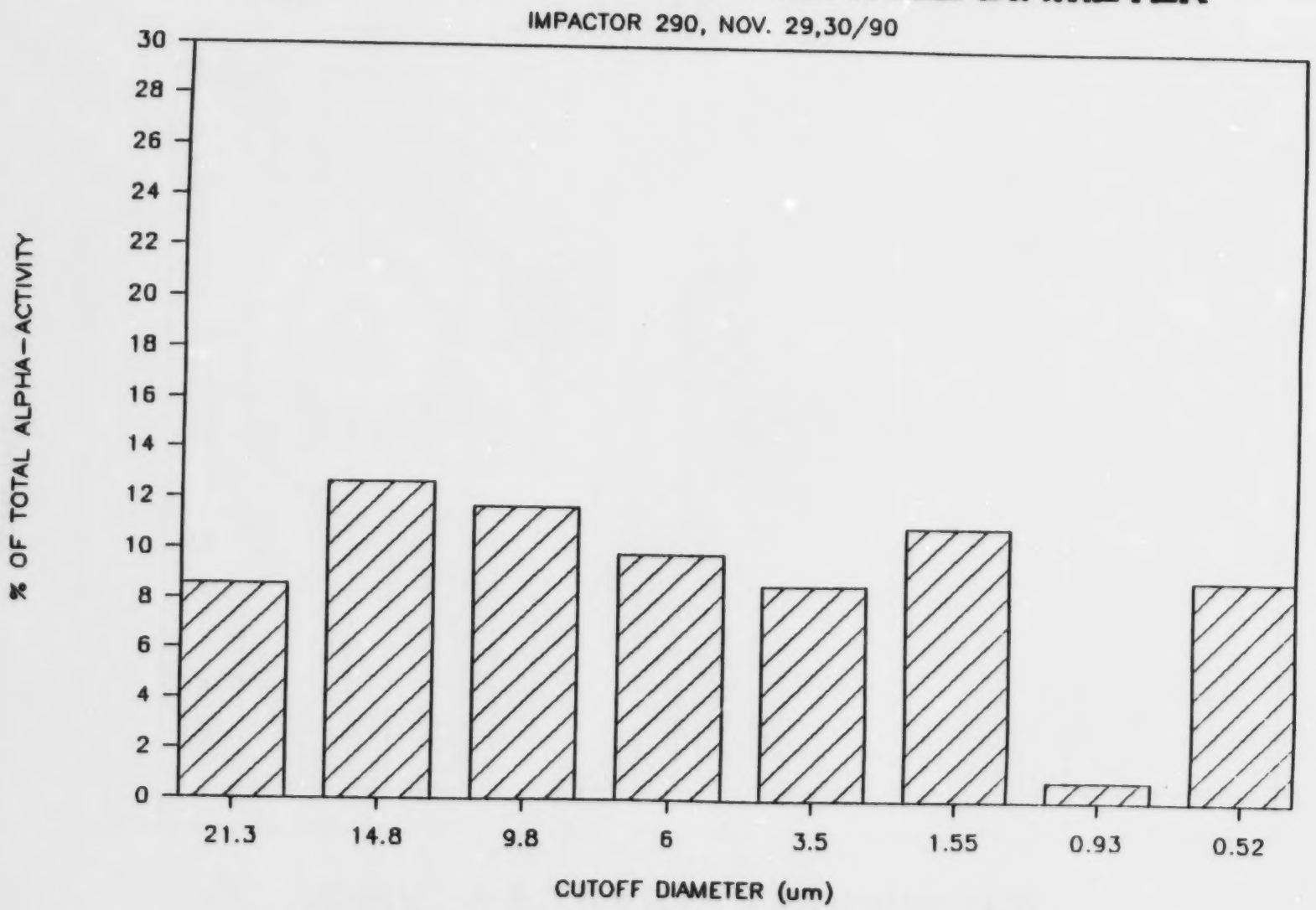


Fig. A4 - Percentage of the total α-particle activity versus cut-off diameter.

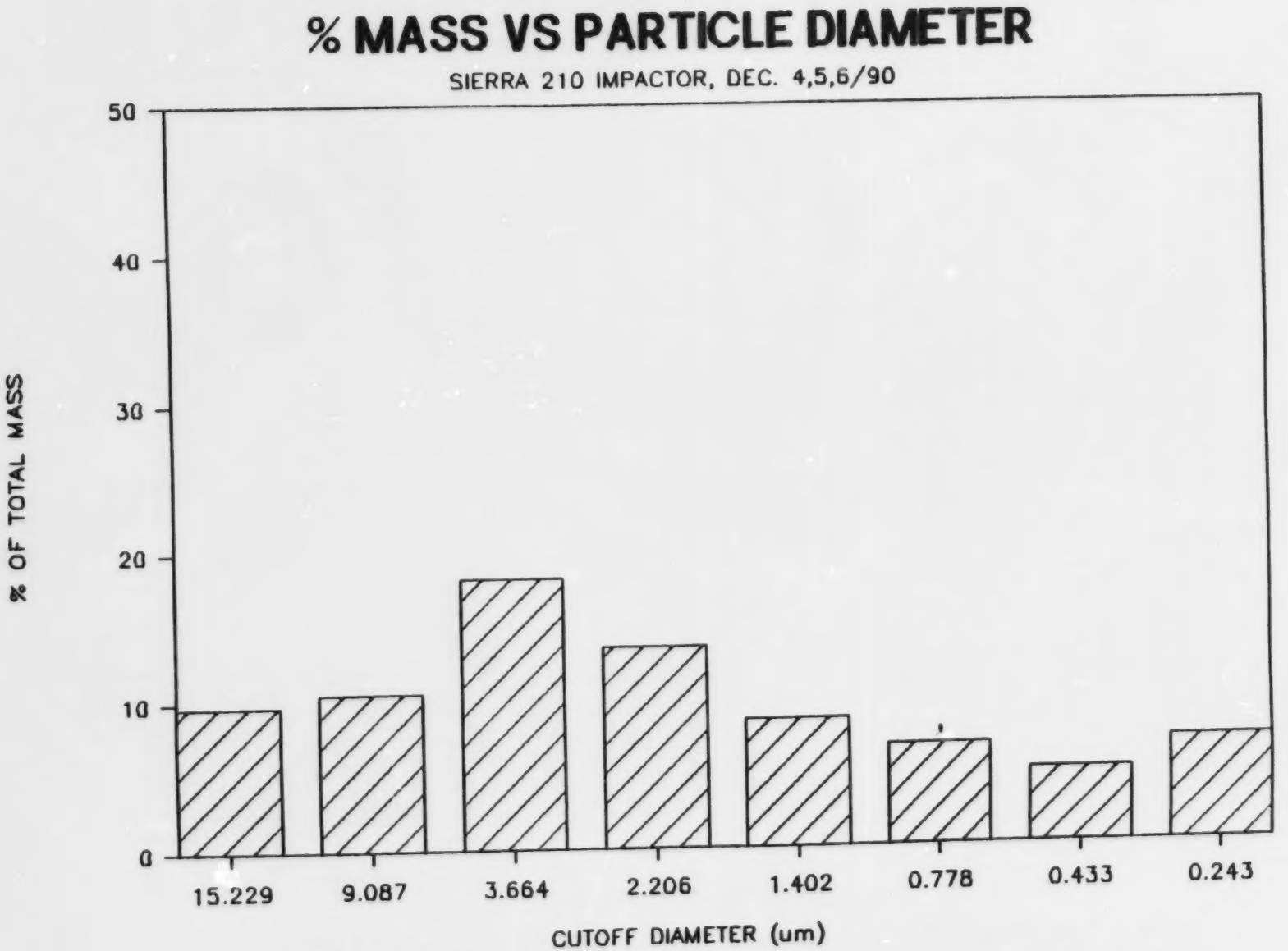


Fig. A5 - Percentage of the total dust mass versus cut-off diameter.

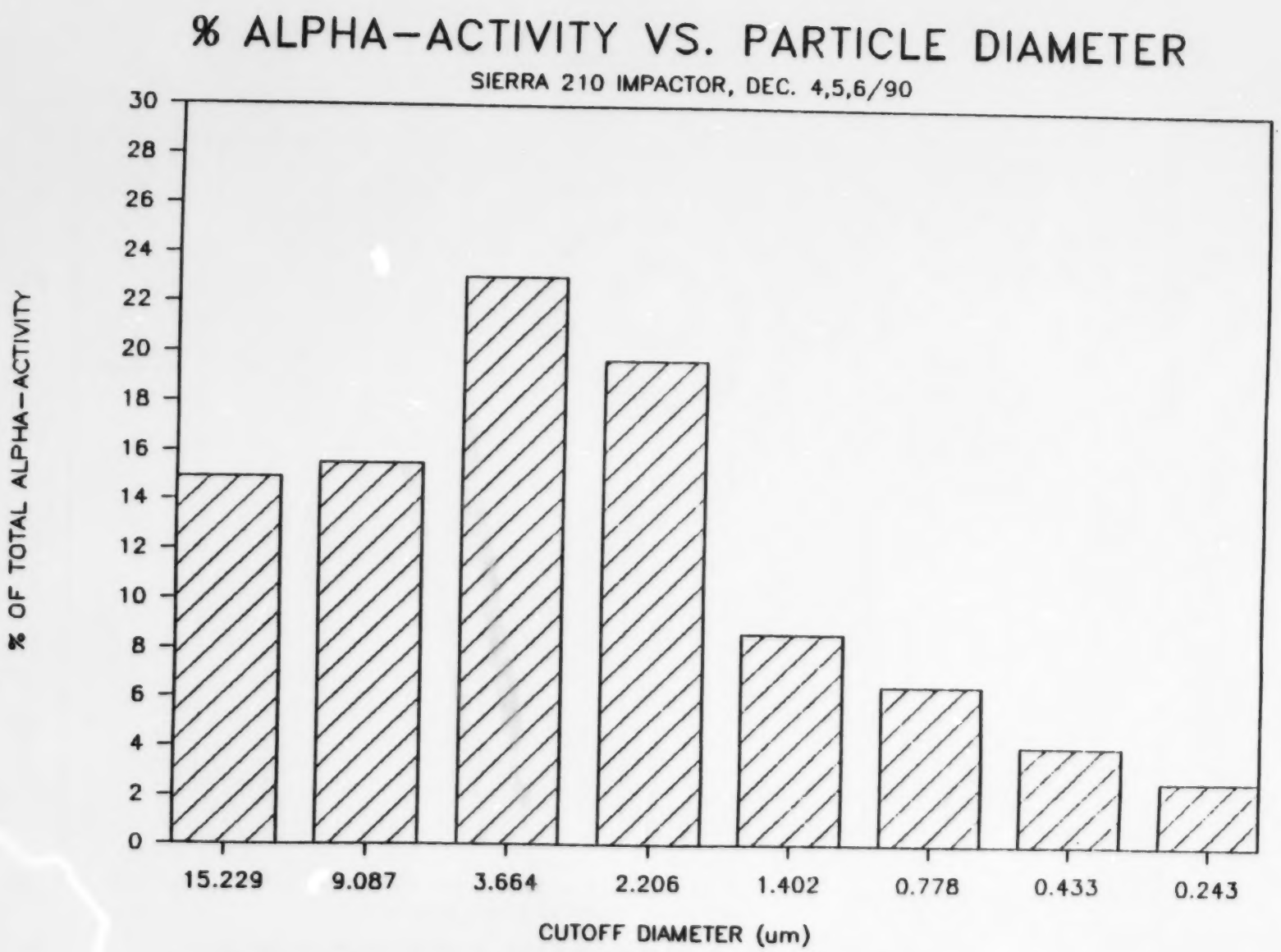


Fig. A6 - Percentage of the total α-particle activity versus cut-off diameter.

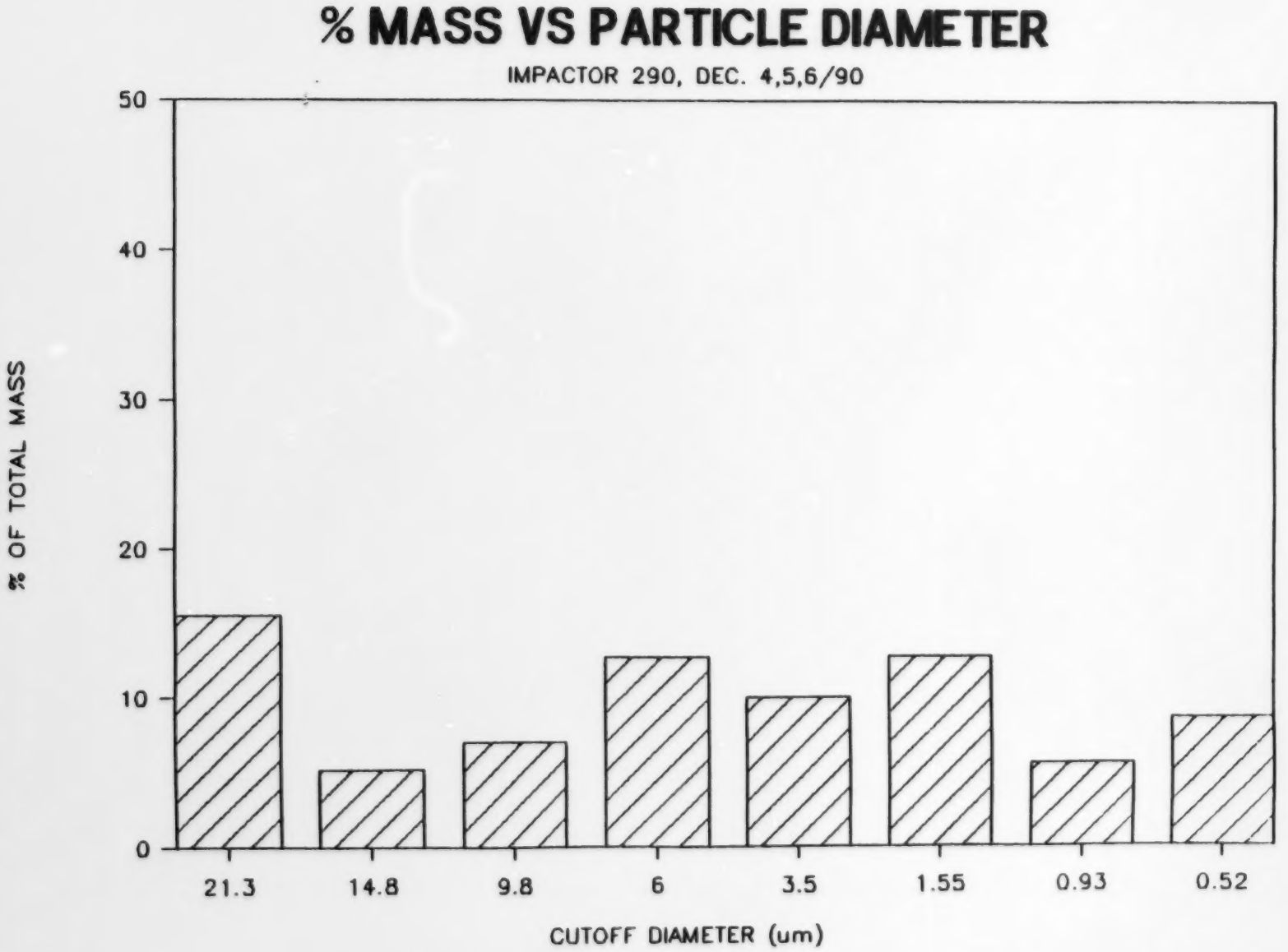


Fig. A7 - Percentage of the total dust mass versus cut-off diameter.

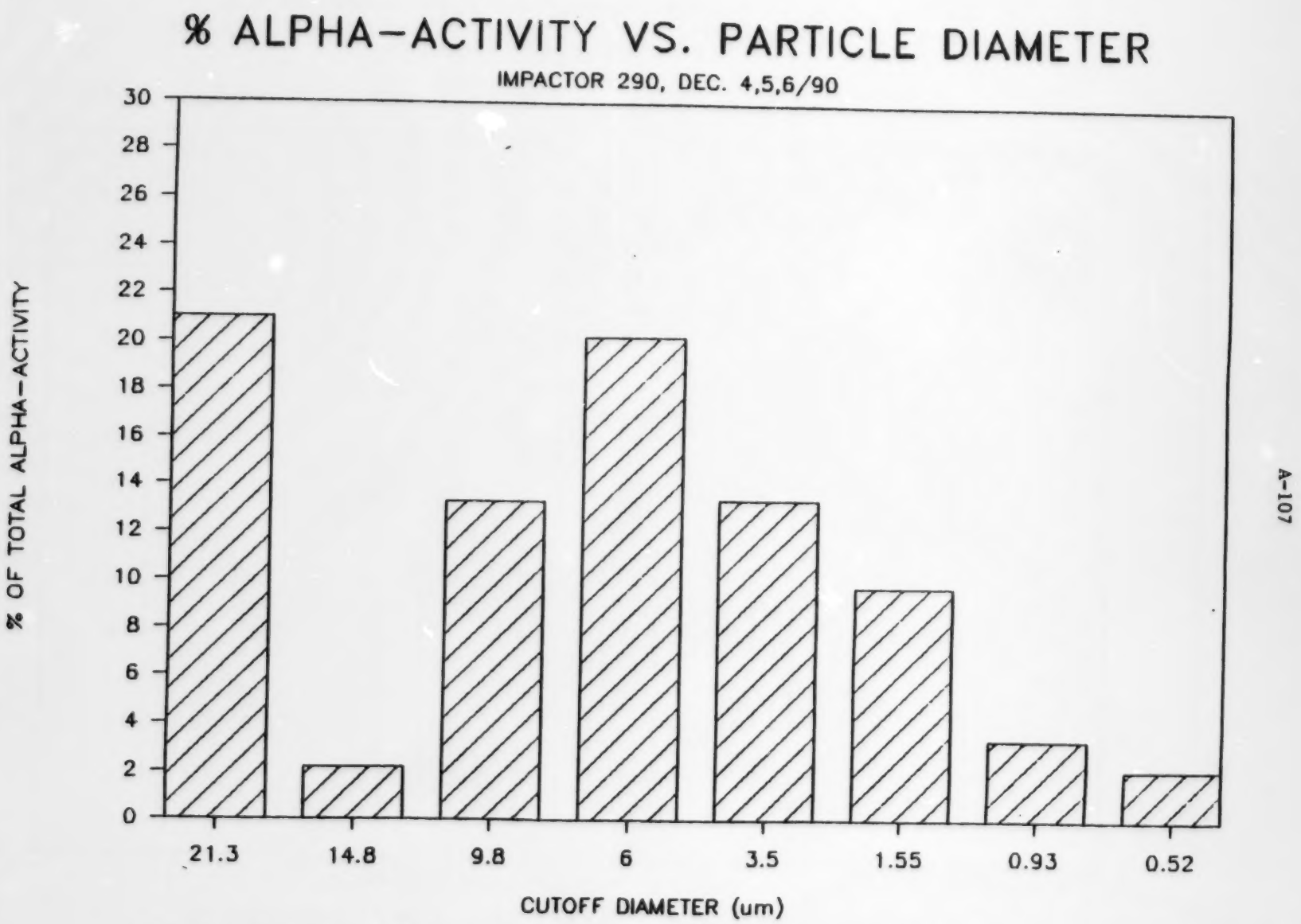


Fig. A8 - Percentage of the total α-particle activity versus cut-off diameter.

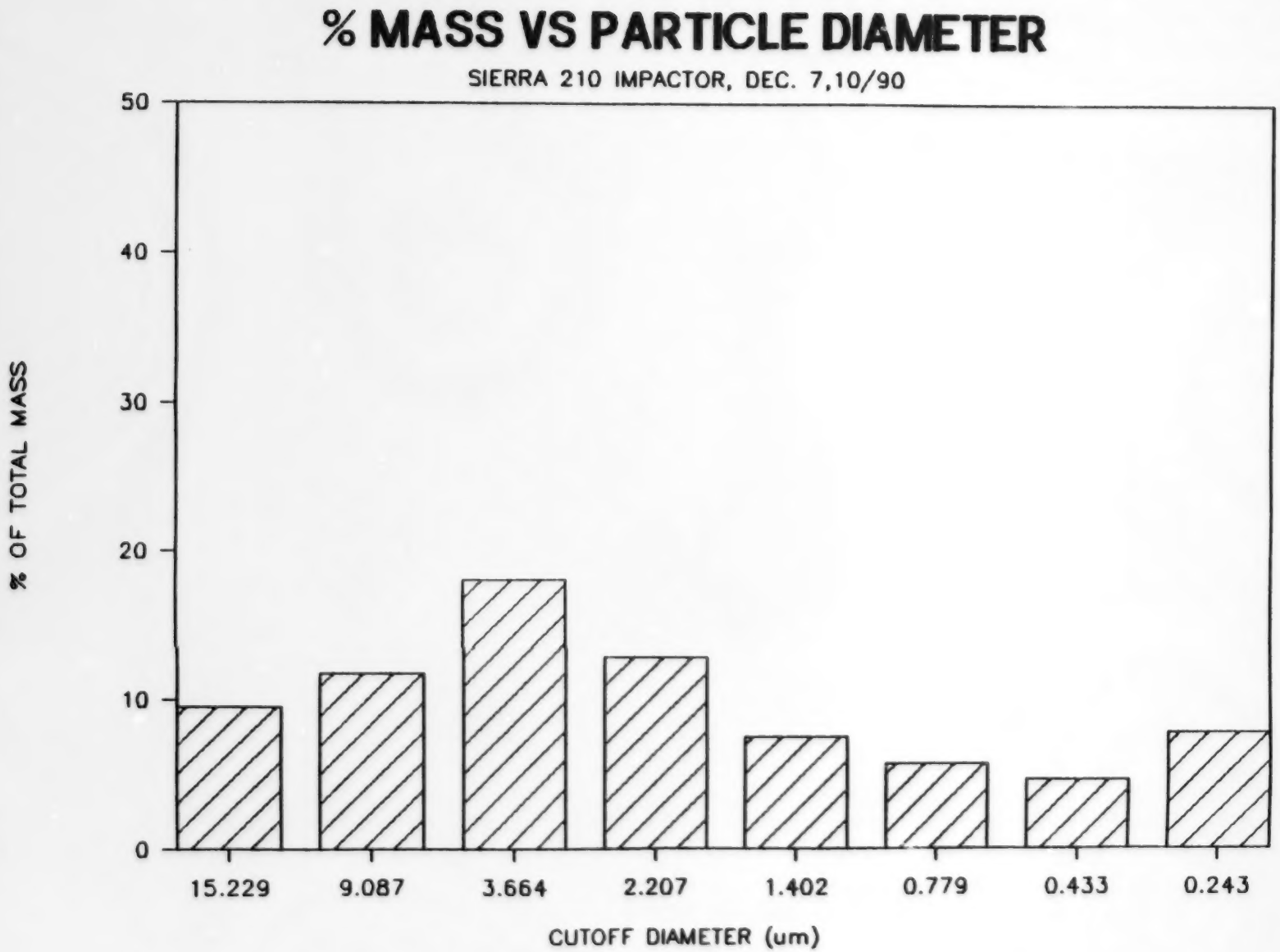


Fig. A9 - Percentage of the total dust mass versus cut-off diameter.

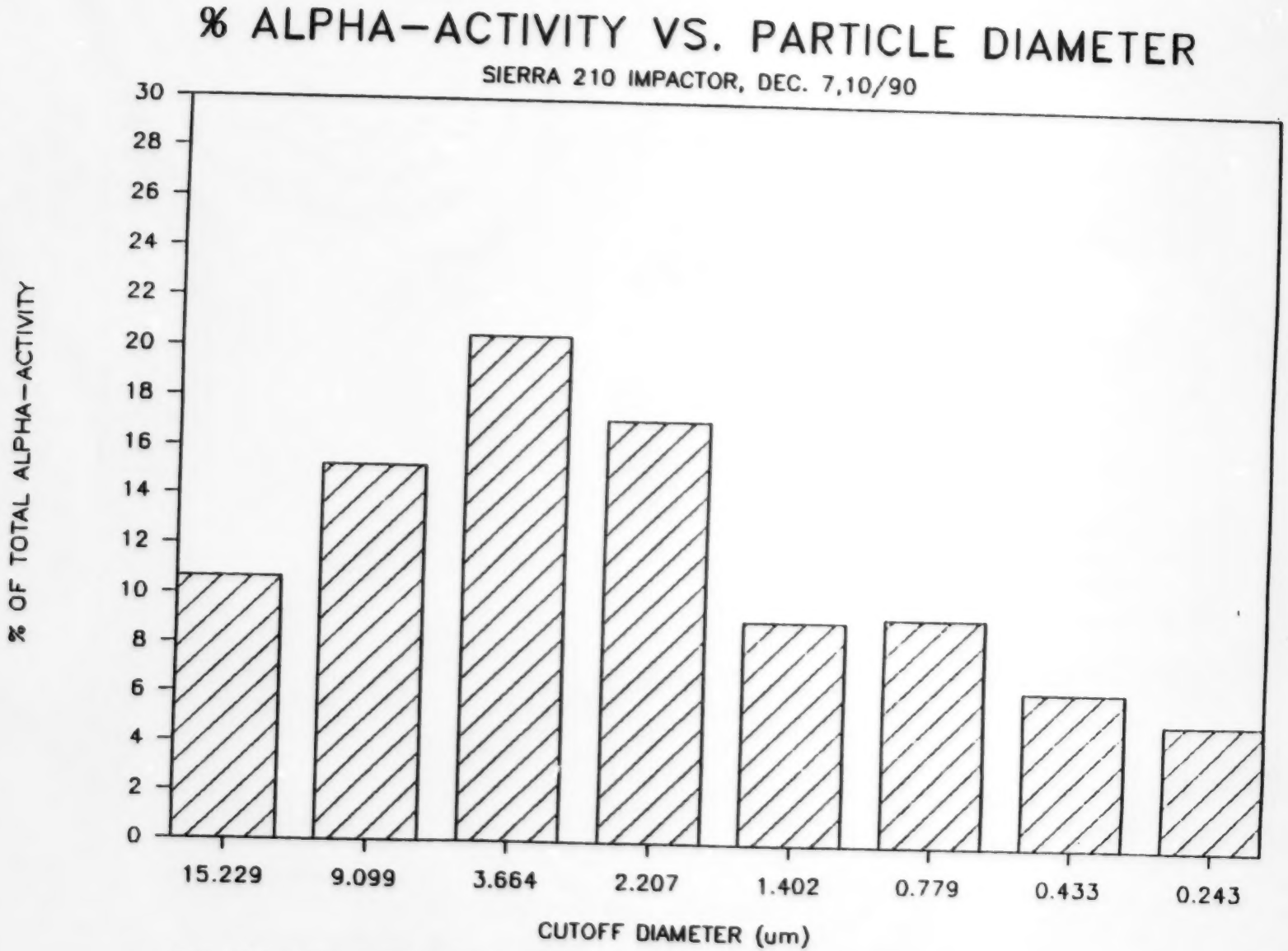


Fig. A10 - Percentage of the total α-particle activity versus cut-off diameter.

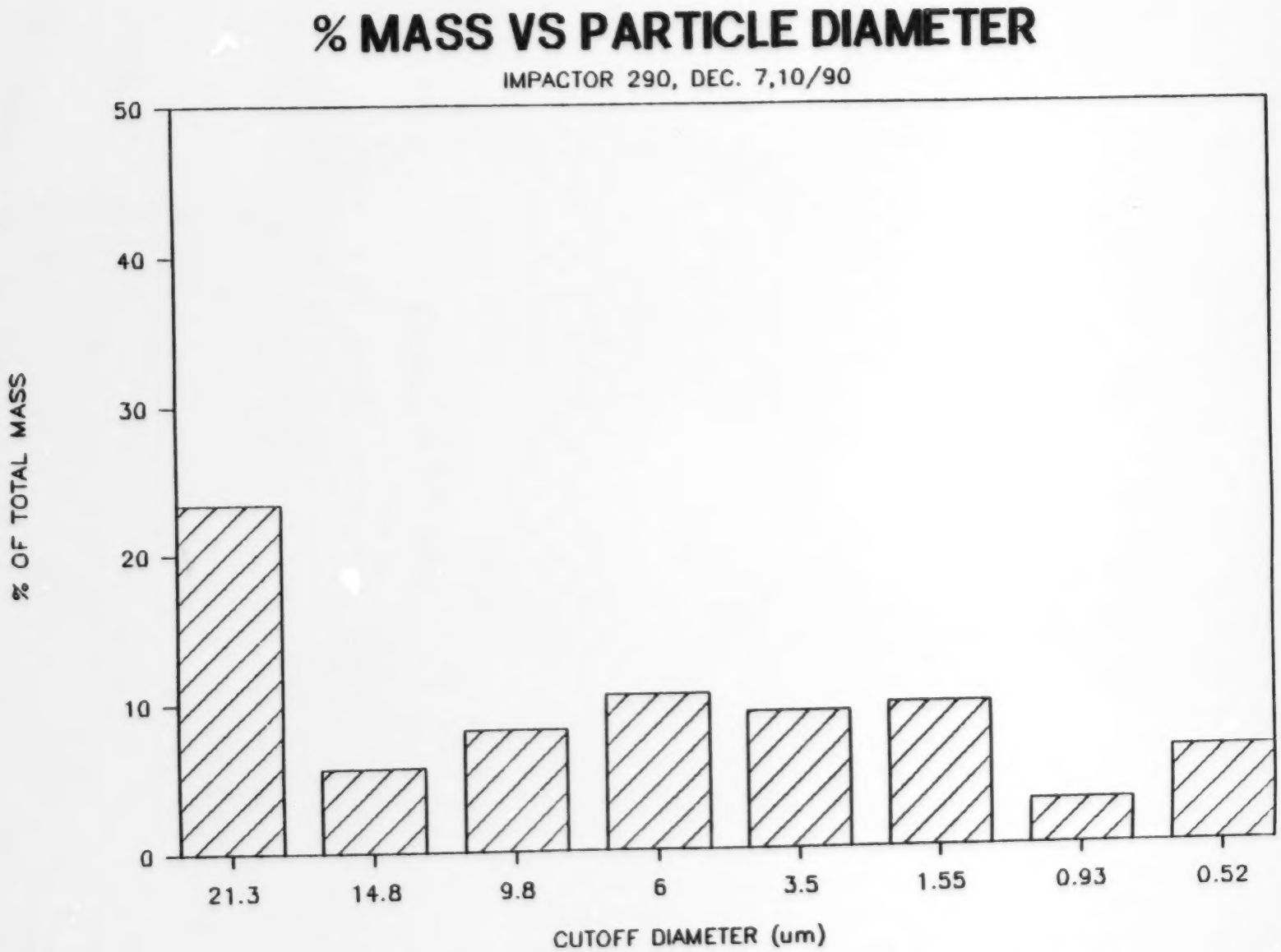


Fig. A11 - Percentage of the total dust mass versus cut-off diameter.

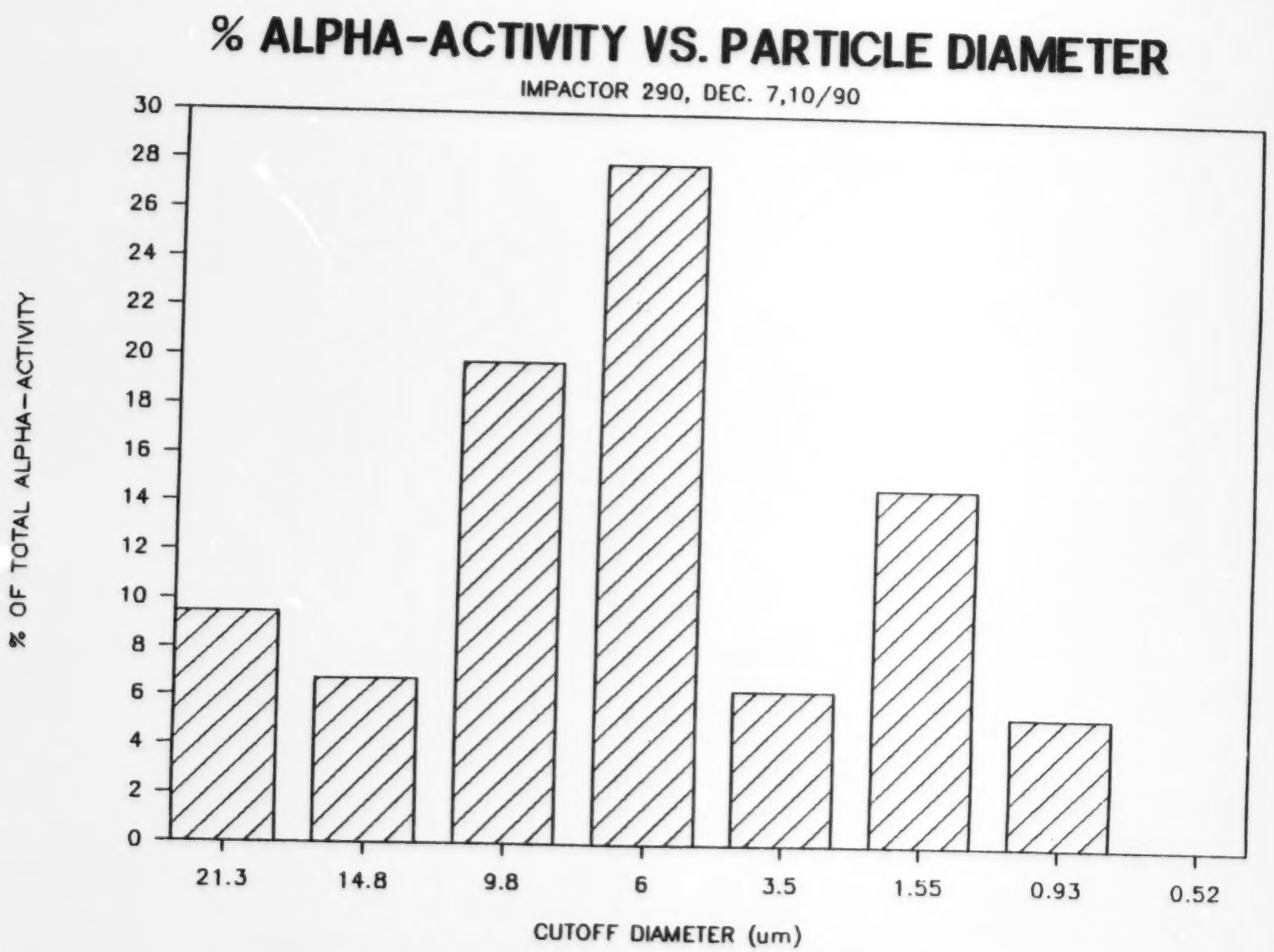


Fig. A12 - Percentage of the total α-particle activity versus cut-off diameter.

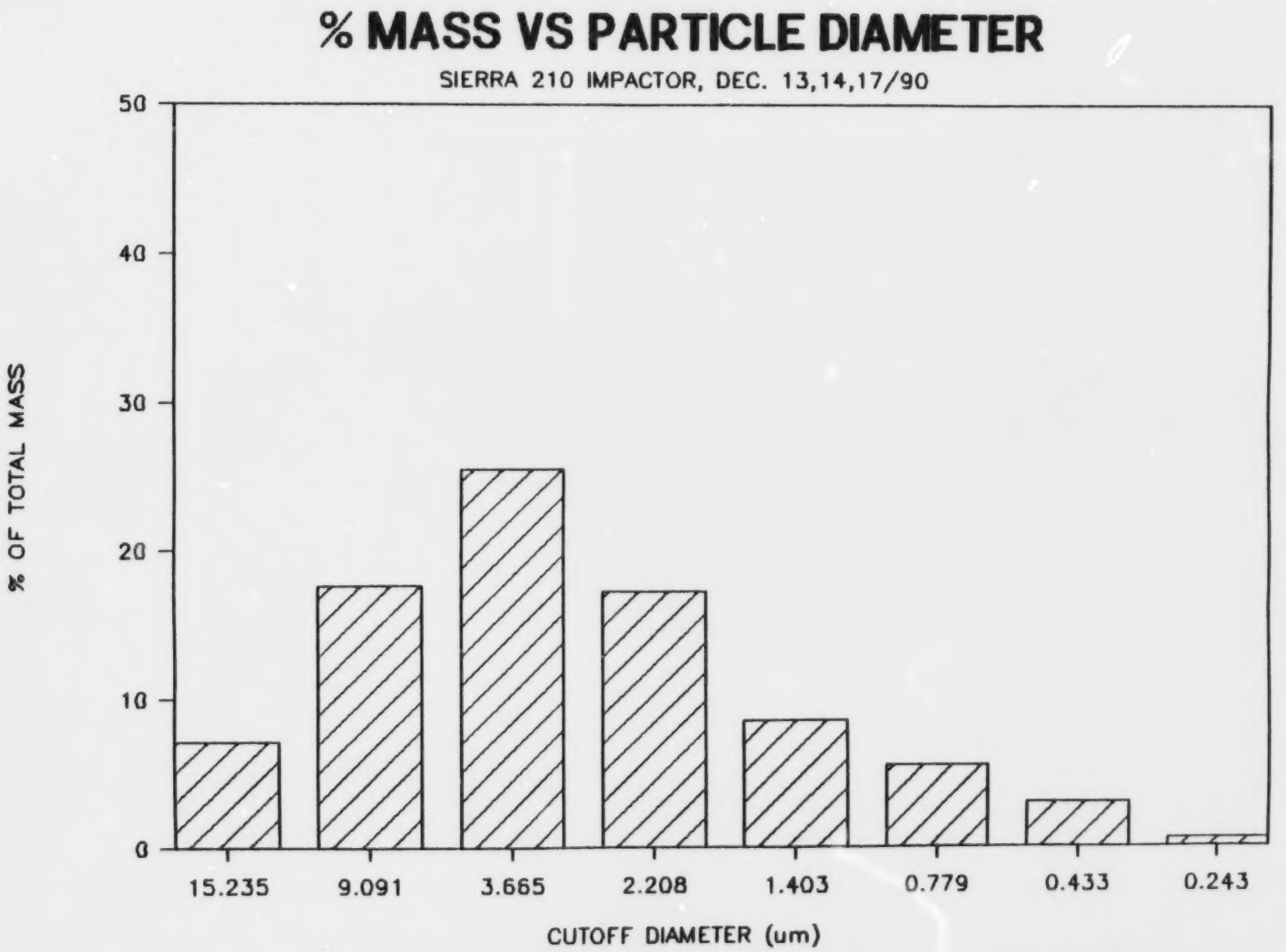


Fig. A13 - Percentage of the total dust mass versus cut-off diameter.

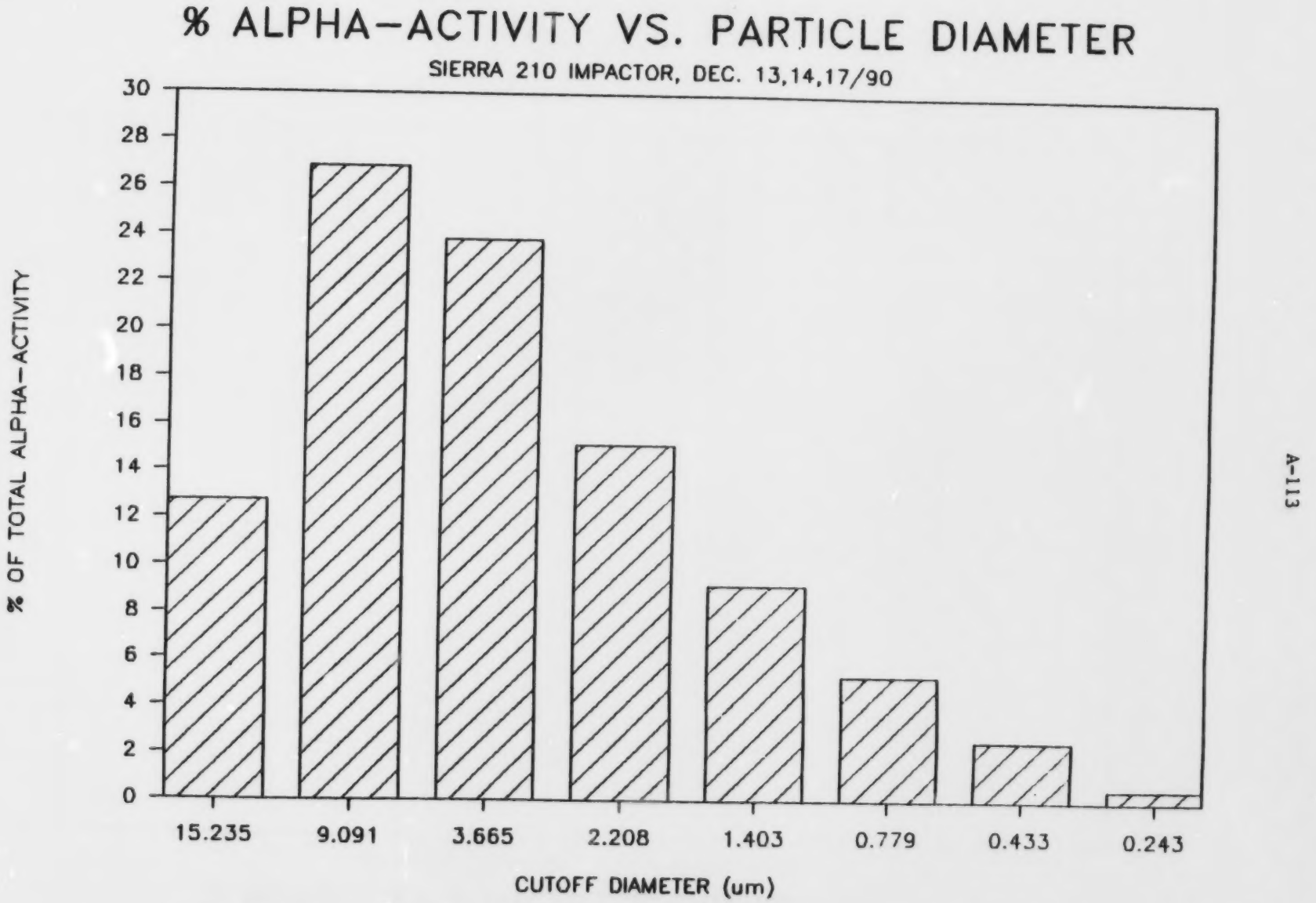


Fig. A14 - Percentage of the total α-particle activity versus cut-off diameter.

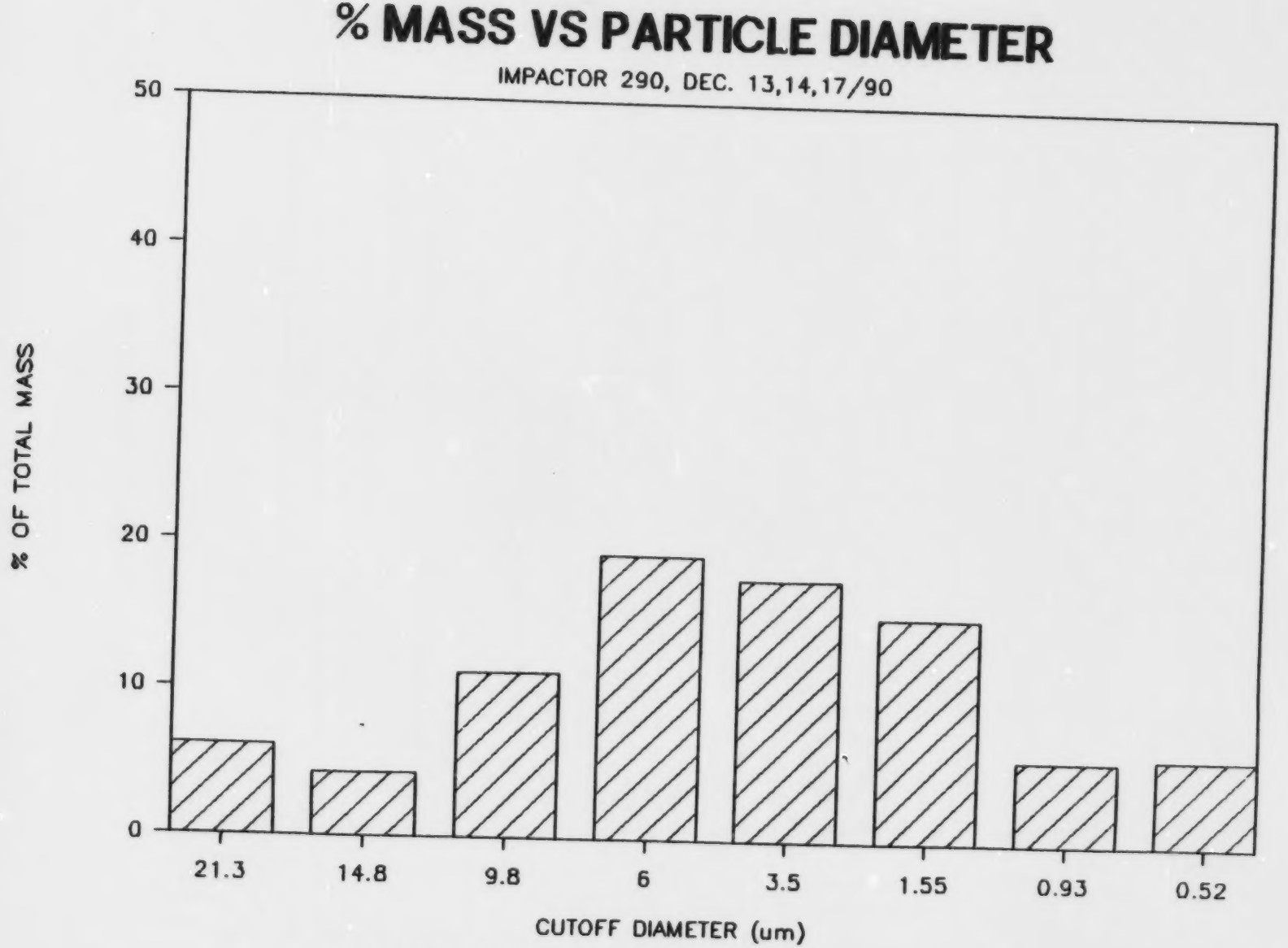


Fig. A15 - Percentage of the total dust mass versus cut-off diameter.

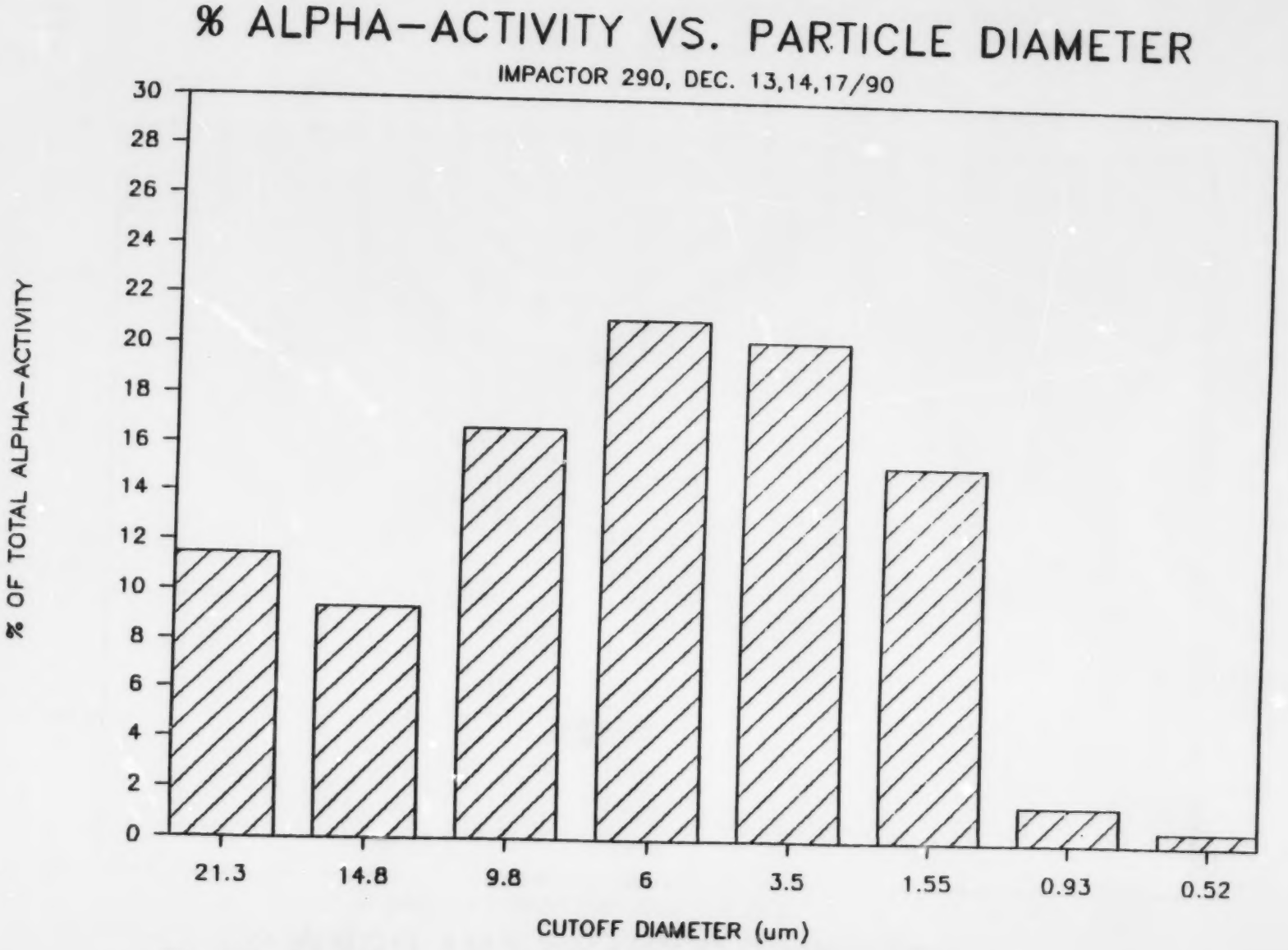


Fig. A16 - Percentage of the total α-particle activity versus cut-off diameter.

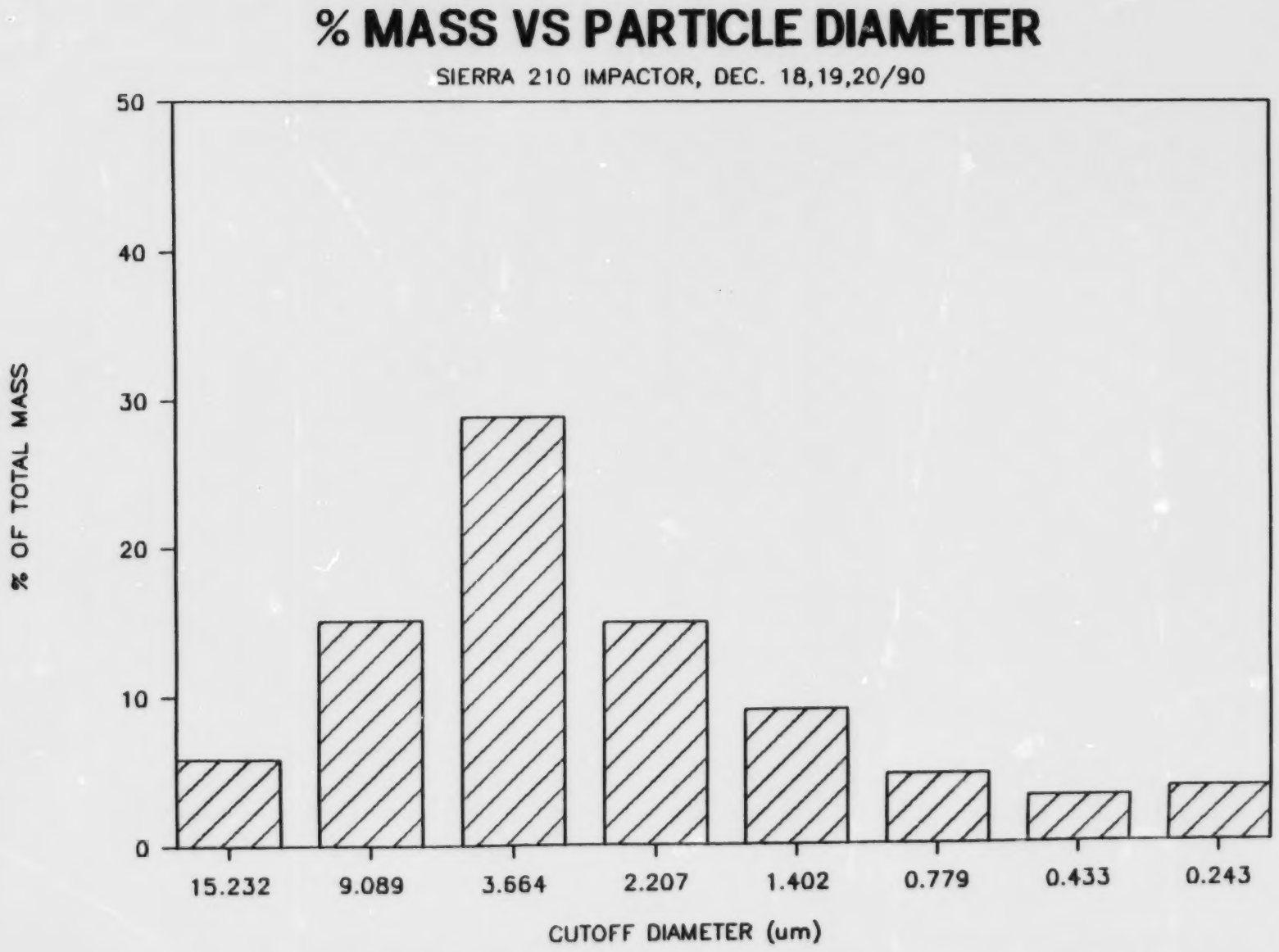


Fig. A17 - Percentage of the total dust mass versus cut-off diameter.

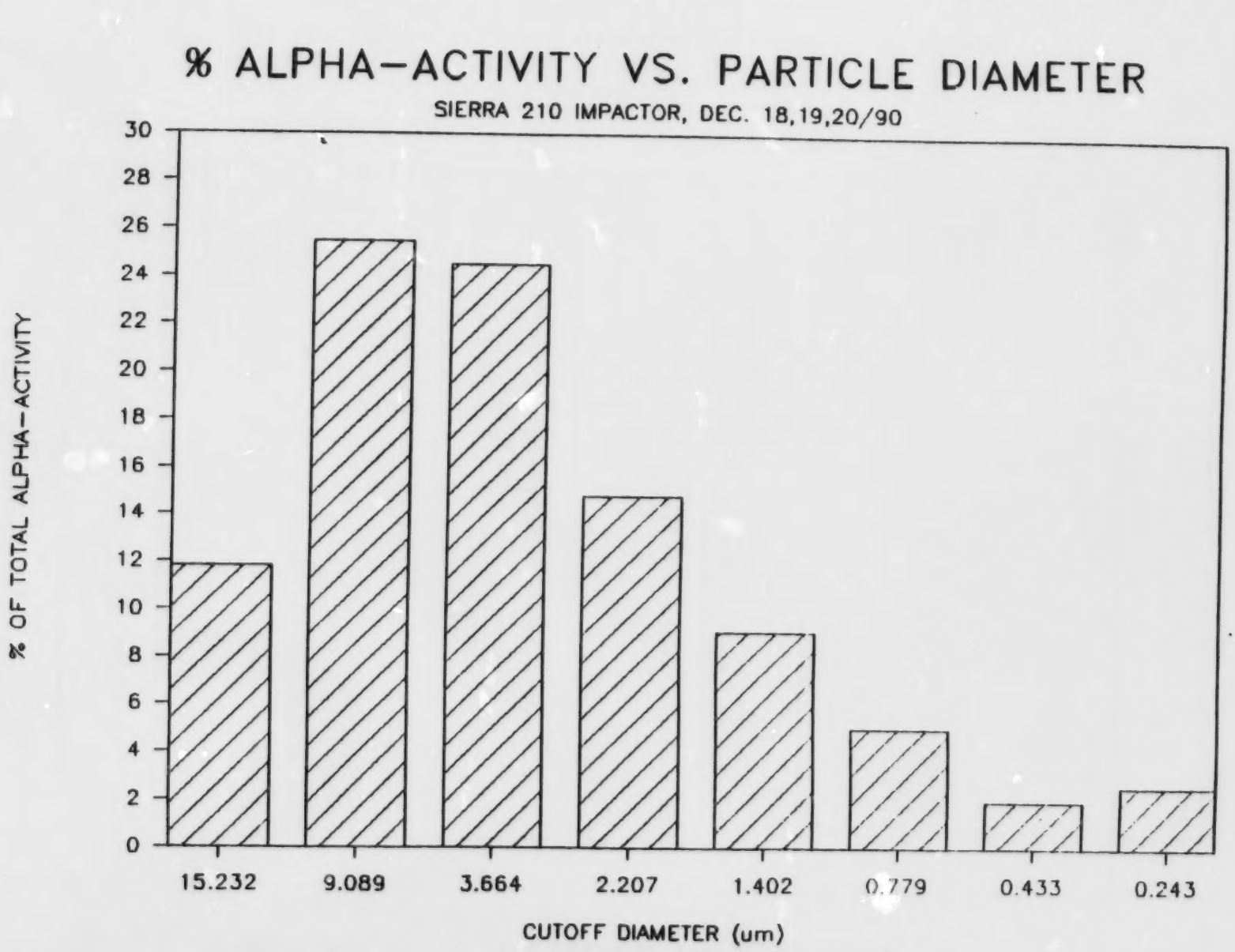


Fig. A18 - Percentage of the total α-particle activity versus cut-off diameter.

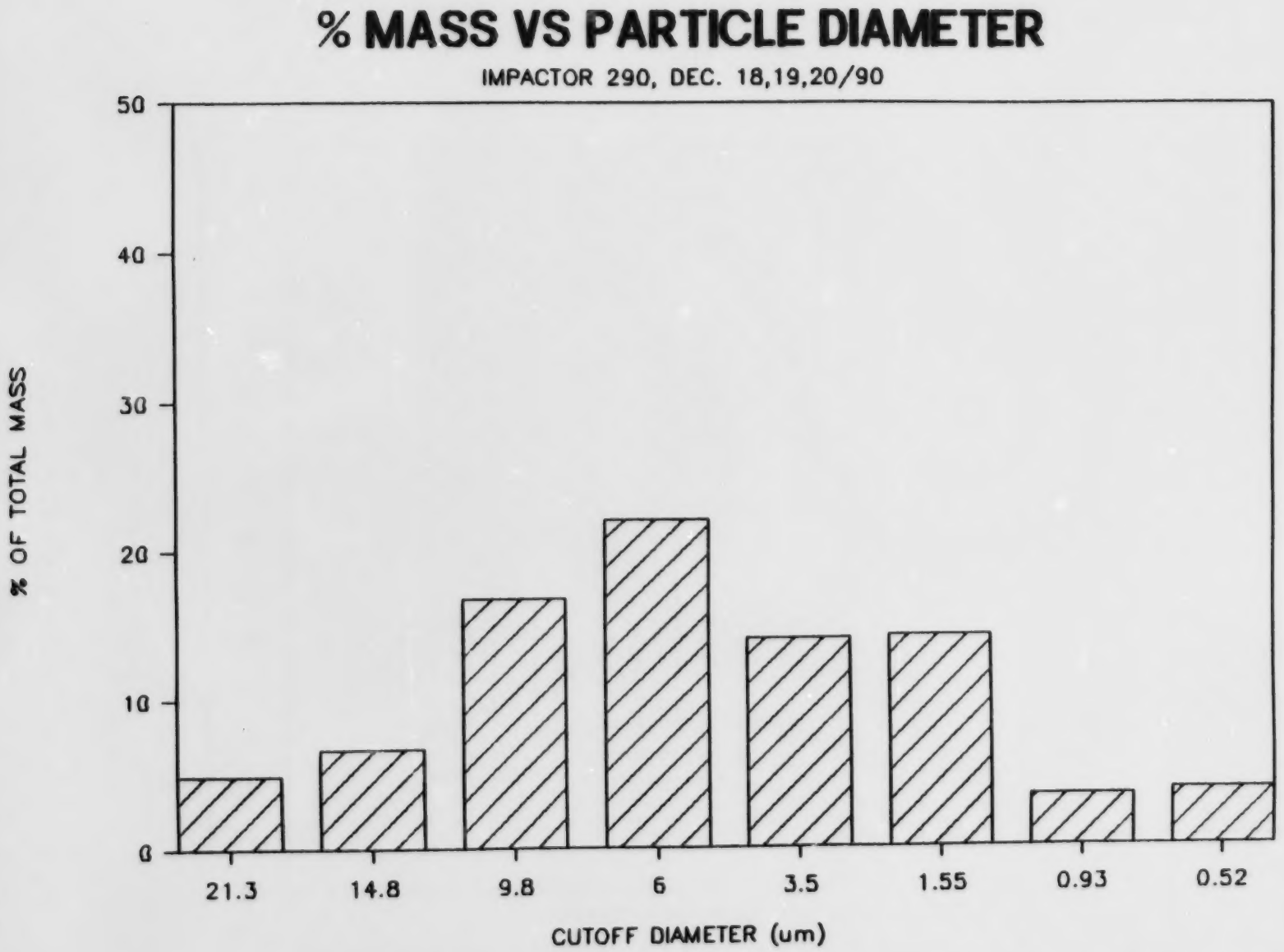


Fig. A19 - Percentage of the total dust mass versus cut-off diameter.

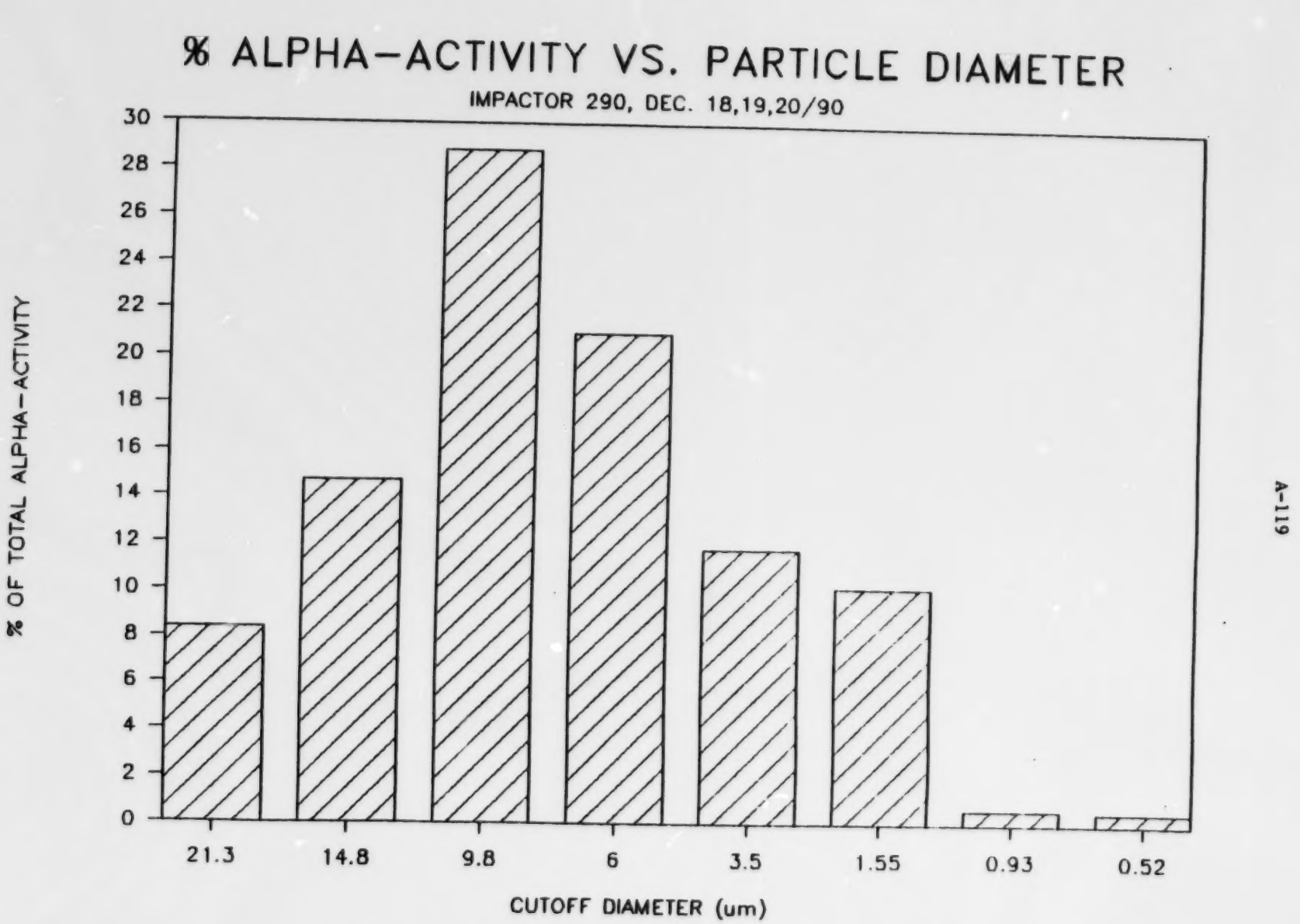


Fig. A20 - Percentage of the total α-particle activity versus cut-off diameter.